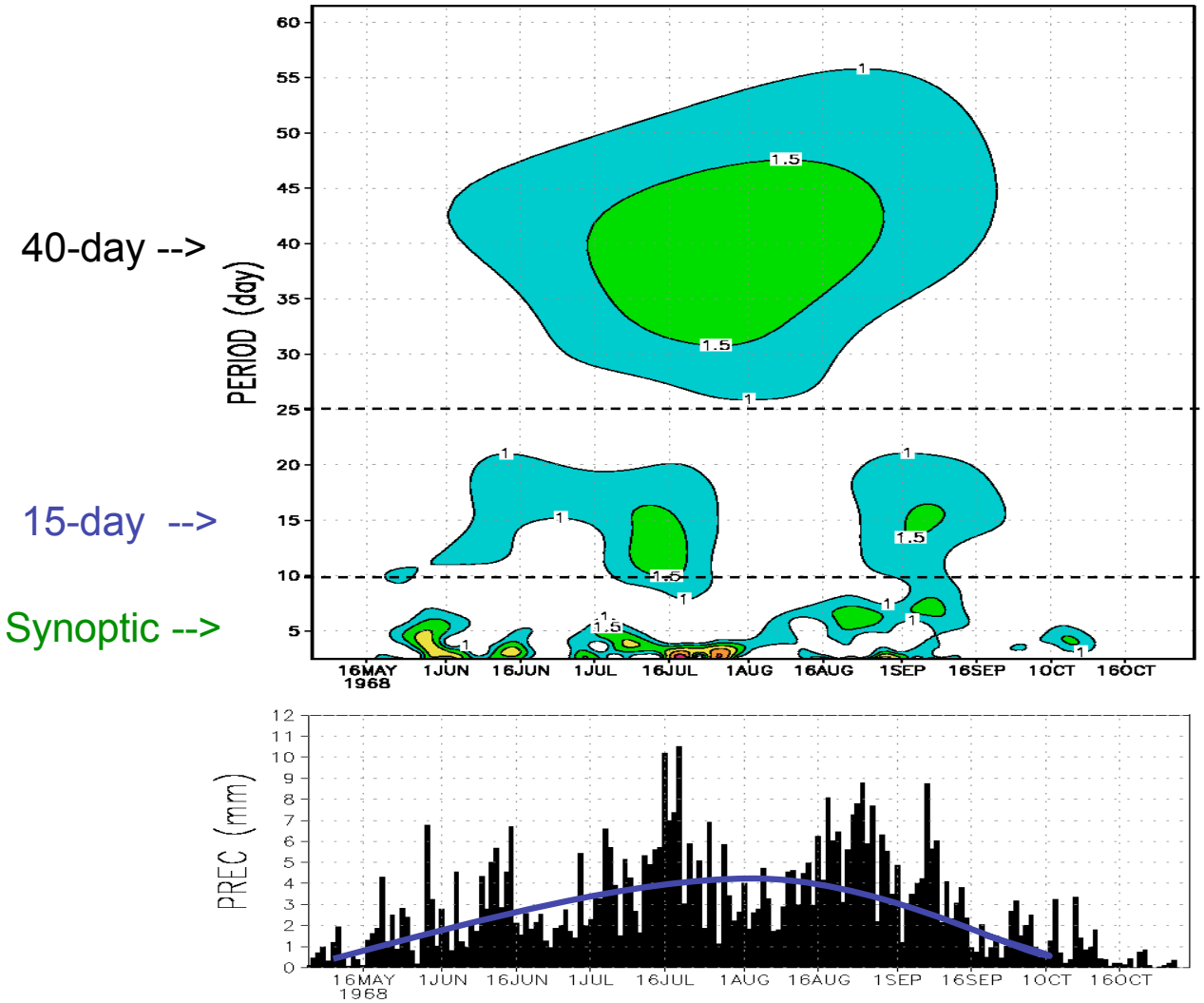
Intra-seasonal variability in the African monsoon

S. Janicot

and contributions of
A. Diedhiou, S. Gervois, G. Kiladis, A. Matthews,
F. Mounier, N. Hall, B. Sultan, C. Taylor

&

What are intra-seasonal time scales in the African monsoon ?



Daily Sahelian rainfall (*IRD data*) from May to October 1968

wavelet analysis

Why studying intra-seasonal variability ?

- Agriculture is strongly rainfall dependent.
- Dry/wet sequence occurrences modulate significantly crop yields.
- Their impact depends also on when they occur in the crop development.
- So a dry sequence occurring during a critical stage of the crop development can induce a bad yield even if the total season rainfall amount is good
- *Farmers needs : onset date, dry spells, withdrawal date*
- Intra-seasonal time scale is presently unpredictable while synoptic and seasonal forecasts are functioning more or less well
- So we need a better knowledge of the related mechanisms

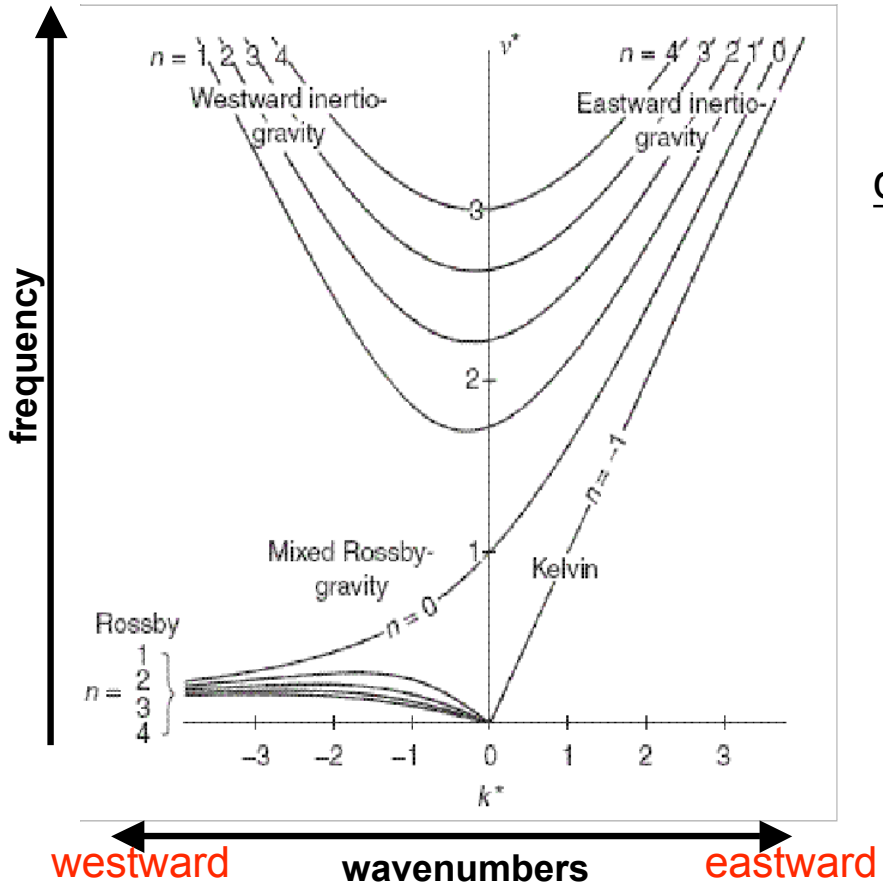
Results presented here is a documentation on June-September data :

- NOAA Outgoing Longwave Radiation data from 1979
  - daily averaged OLR data on a regular 2.5° grid
- NCEP-2 reanalyses from 1979
  - Daily averaged data on a regular 2.5° grid
- IRD rainfall data from 1979
  - Daily data on a regular 2.5° grid over land

- Pre-filtering of the data
- EOF decomposition
- Composite analyses

- Using shallow water model wave solutions

Wave families solution of the shallow water model



dispersion curves

Separation apart of the equator into:

- Symmetric
- Anti-symmetric

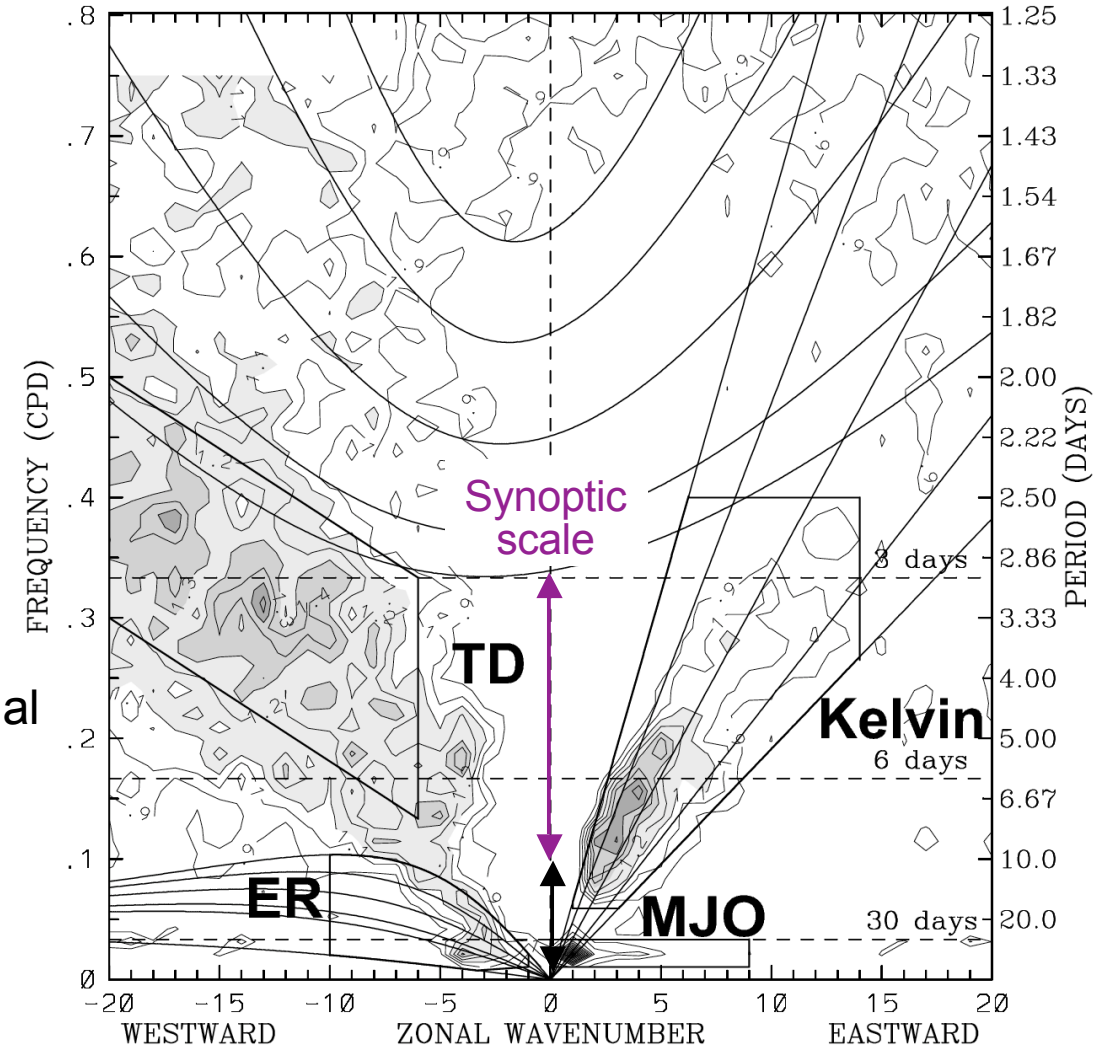
➔ β-plan approximation (the Coriolis parameter is linearly proportional to the latitude)

➔ constrain of a decay of the solutions away from the Equator (equatorially-trapped)

Detection

- Wavenumber-frequency analysis of OLR in June-September 1979-2000 over the whole tropics

  symmetric component
  (Wheeler & Kiladis 1999)



Identify convectively-coupled signal

- Kelvin waves
- Equatorial Rossby waves
- Tropical Depression signal
- MJO signal

Detection

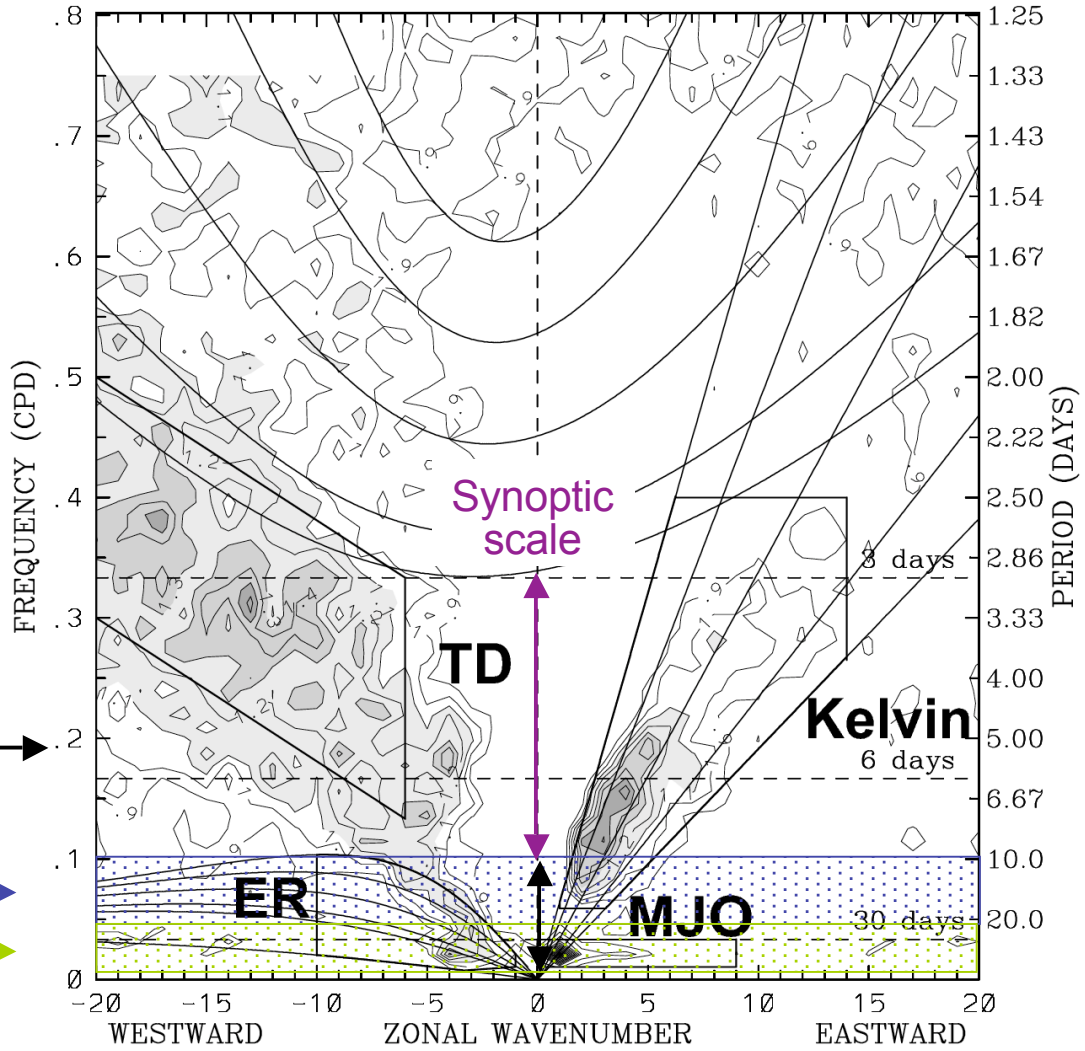
- Wavenumber-frequency analysis of OLR in June-September 1979-2000 over the whole tropics

  symmetric component
  (Wheeler & Kiladis 1999)

Different boxes filtering

10-25-day

25-90-day



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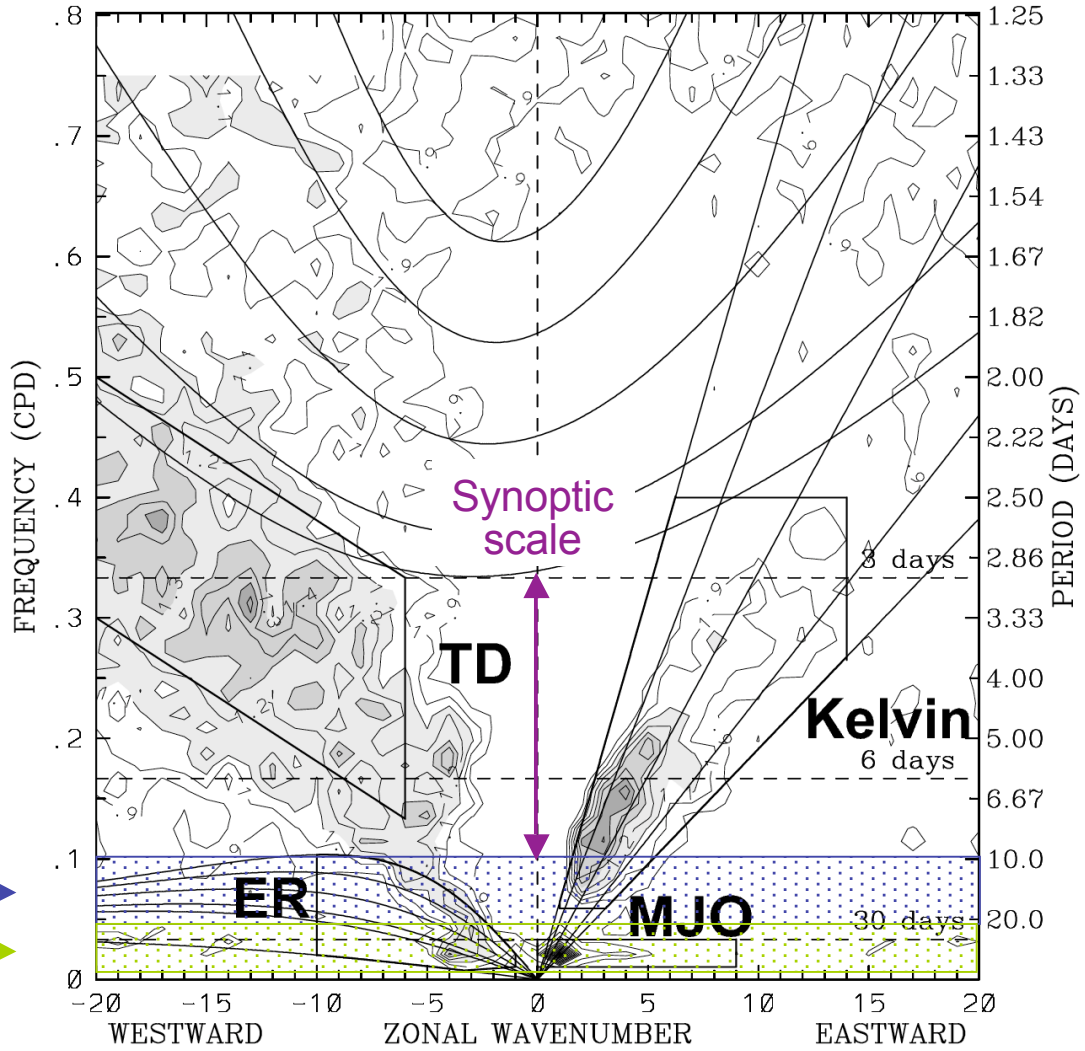
EOF analysis of filtered OLR in June-September over Africa

10-25-day →

25-90-day →



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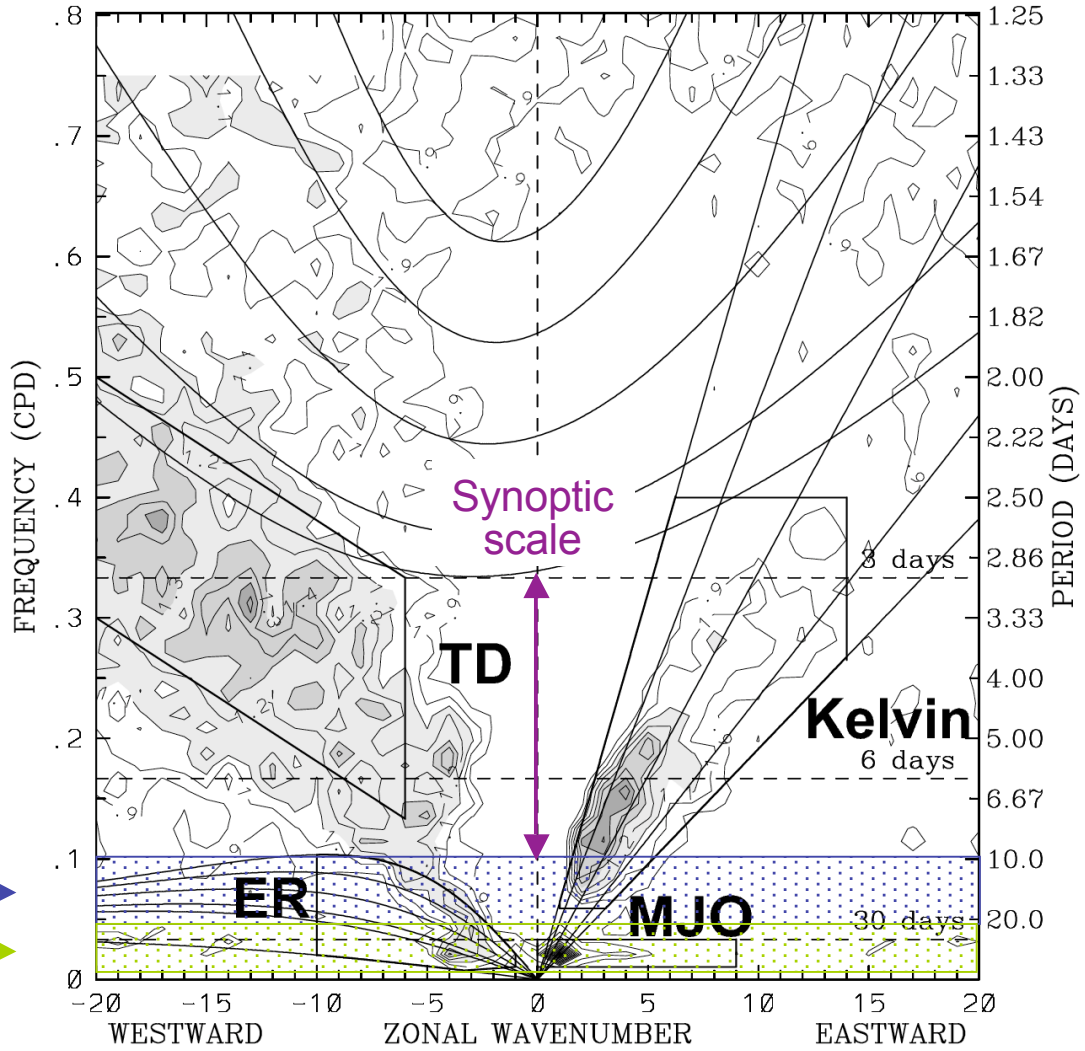


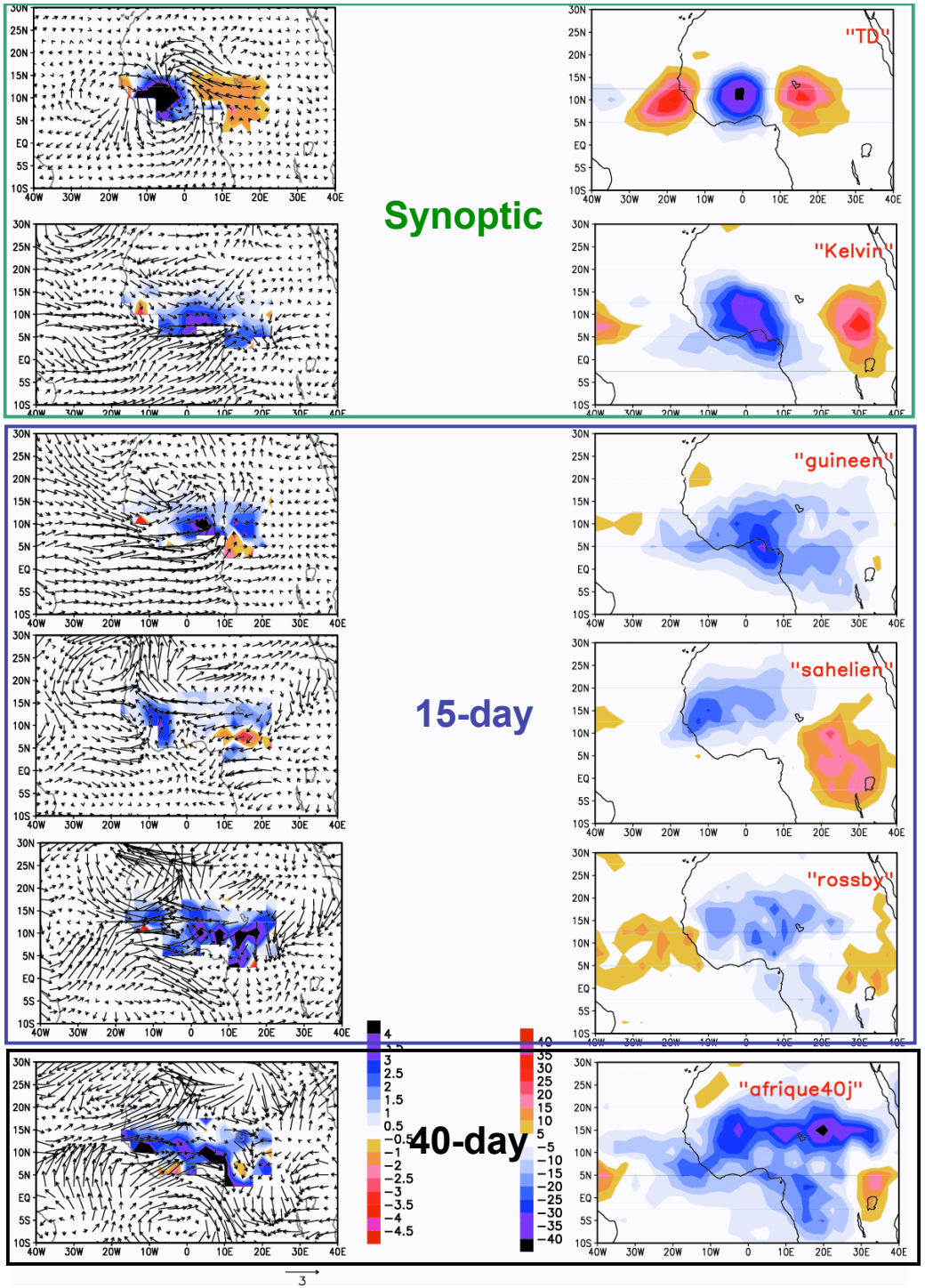
Composite of unfiltered OLR fields of (wet - dry) events / reconstruction of ITCZ 10°W-10°E OLR index

Detected modes over West and Central Africa

Wet minus dry events

Left: V925hPa and rainfall over land

Right: OLR

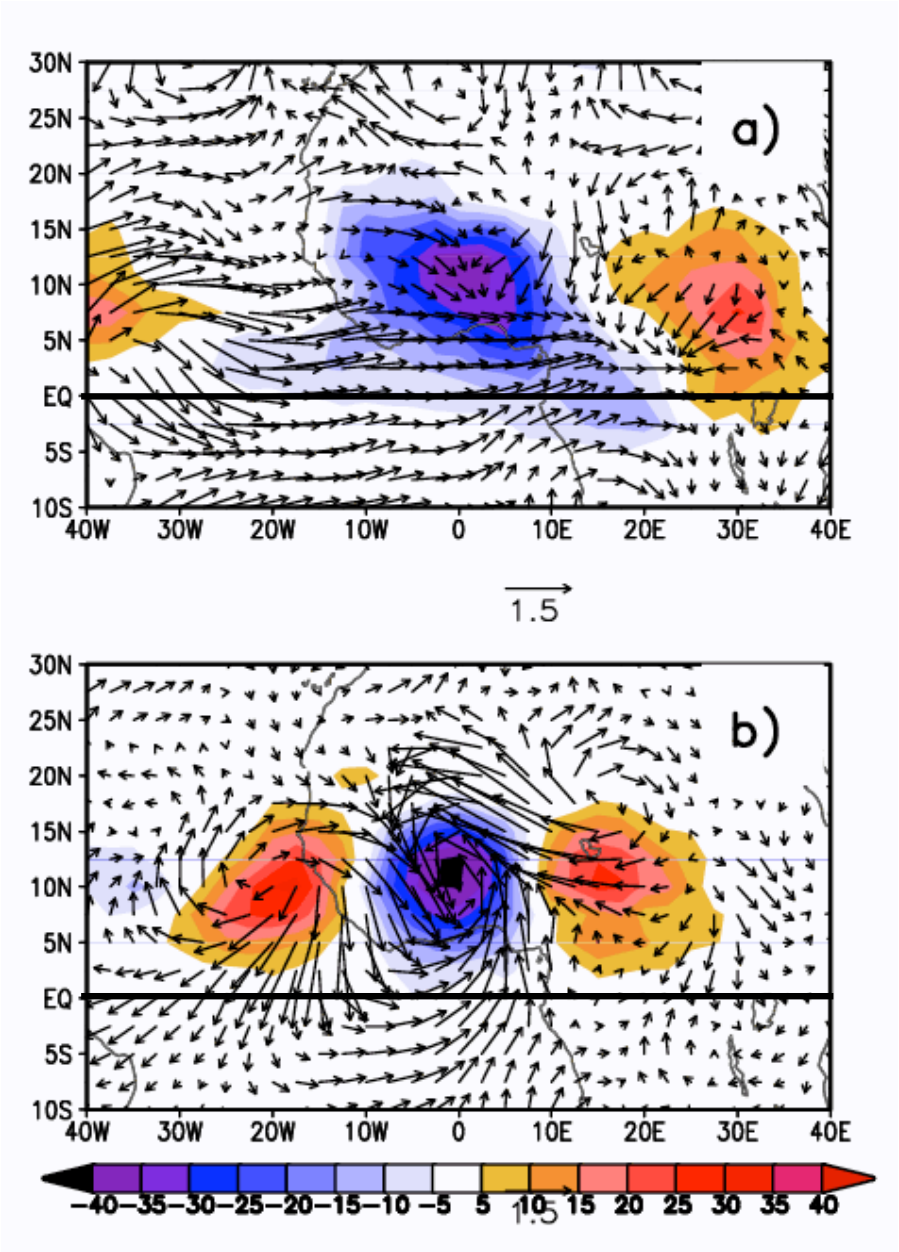


Kelvin waves & Easterly waves

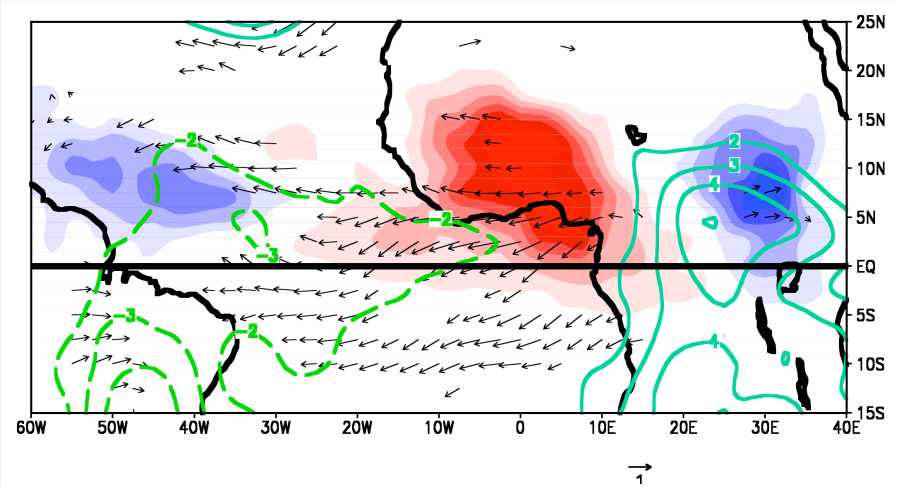
Composite for Kelvin waves

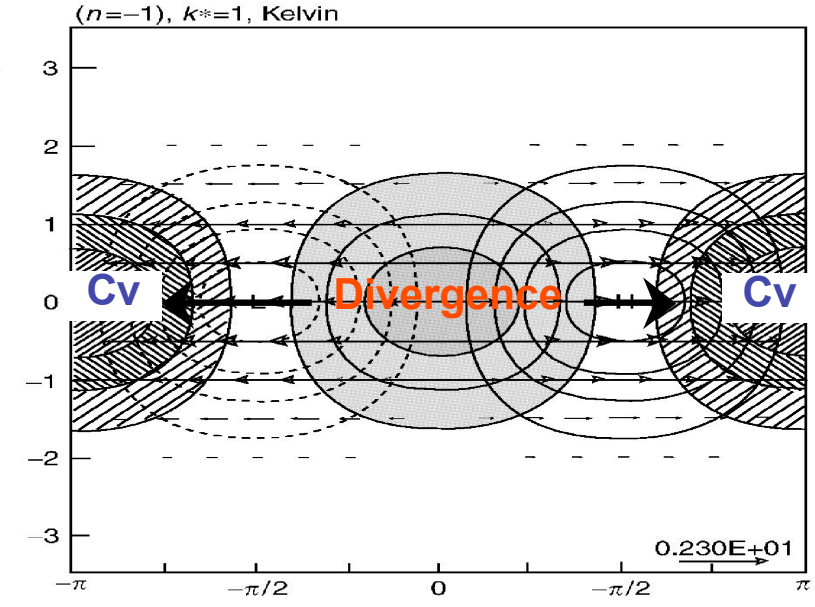
OLR & V925hPa

Composite for Easterly waves (TD)



Kelvin wave pattern



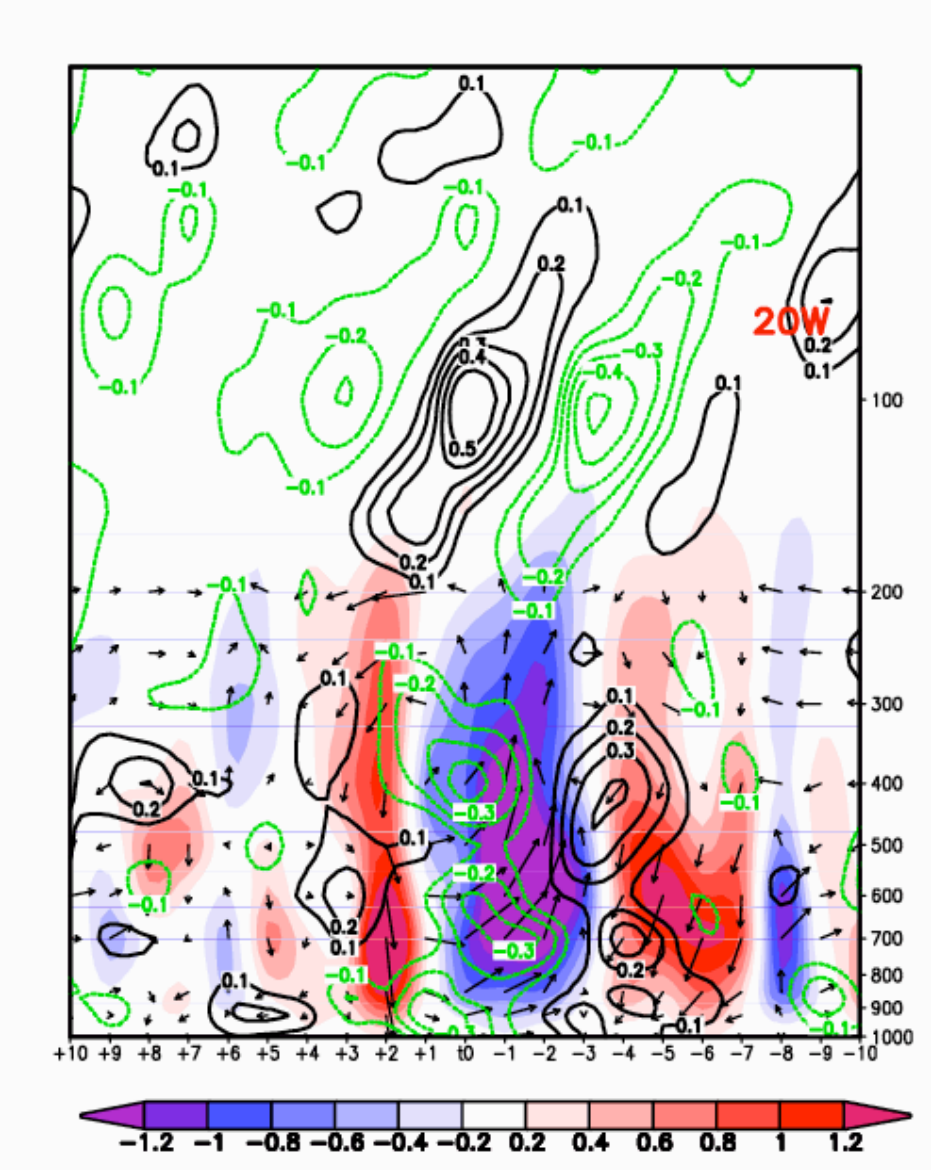


- Convection anomalies coherent with convergence & divergence
- Coupling with convection / northward shift (follows the ITCZ)
- Enclosed into geopotential anomalies / wind anomaly coherent over the ocean and symmetric / 5°N

Theoretical Kelvin horizontal structure in a dry atmosphere

Matsuno 1966

OLR and 925hPa wind and geopotential



wet - dry events

Vertical-time section

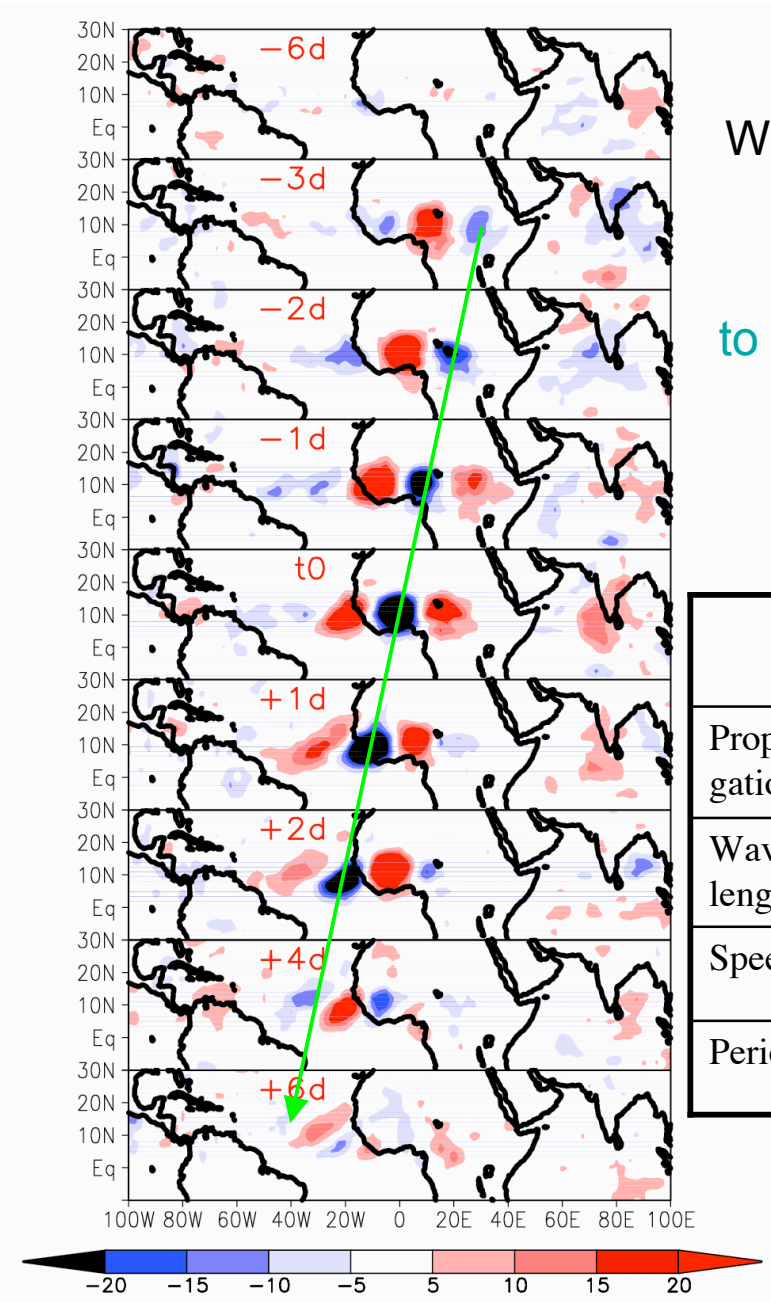
of the Kelvin wave at 20°W

- vertical velocity shaded

- zonal-vertical wind vectors

- temperature isolines

Easterly waves - Synoptic scale - Kelvin waves

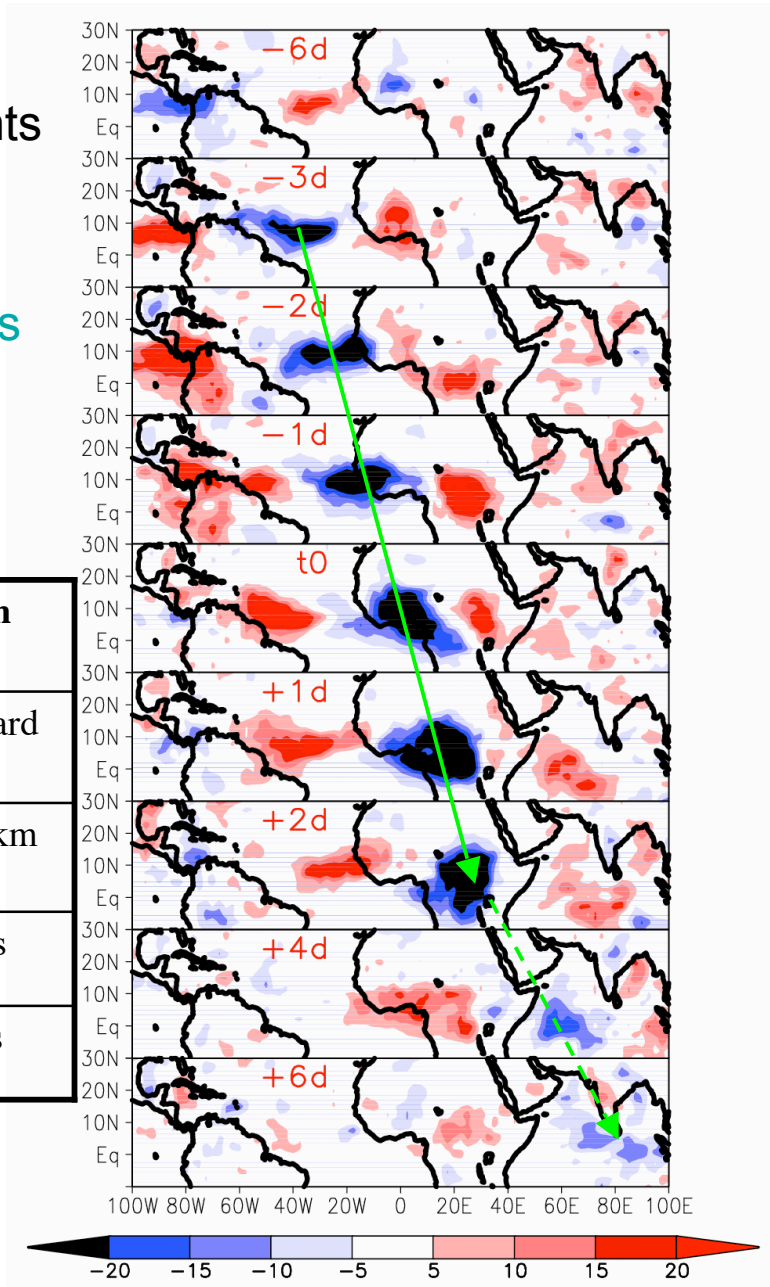


Wet minus dry events

OLR

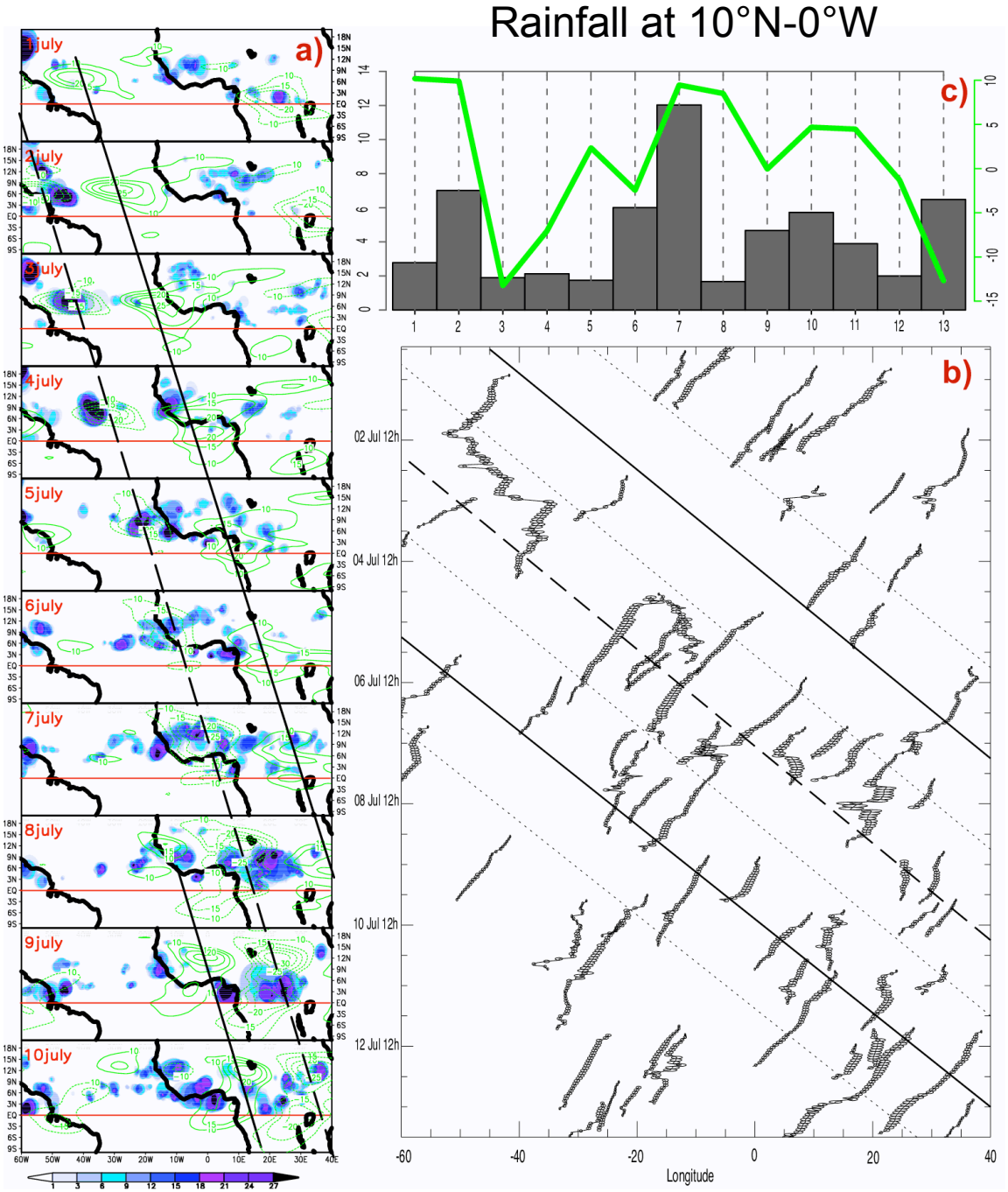
to - 6 days / + 6 days

	Easterly wave	**Kelvin wave**
Propa-gation	westward	eastward
Wave-length	4000 km	8000 km
Speed	11 m/s	15 m/s
Period	4 days	6 days

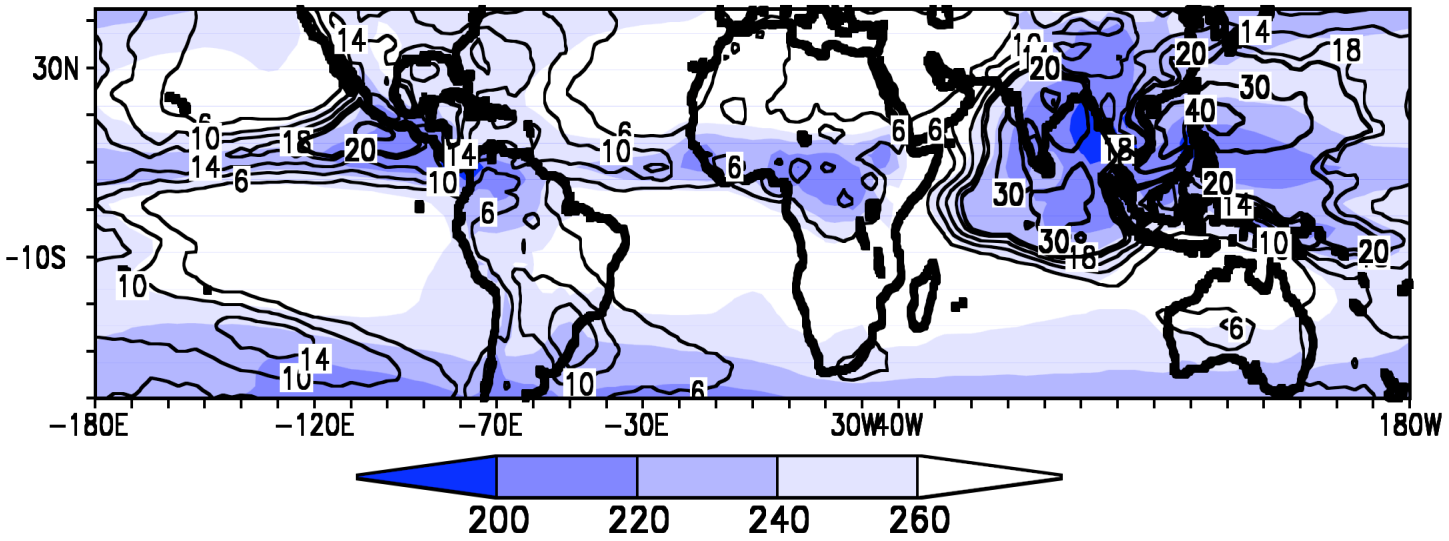


A Kelvin wave occurrence during 1 - 10th July 1984

Kelvin wave are moving eastward and modulate the activity of individual convective systems



10-90 days filtered
OLR-NOAA

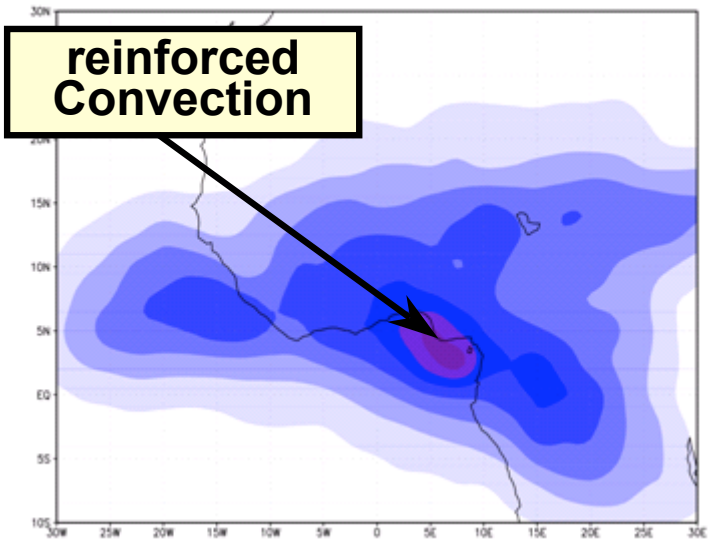


OLR June-September

Variance in contours

EOF on OLR filtered between 10 and 90 days

EOF1 / 13.34%

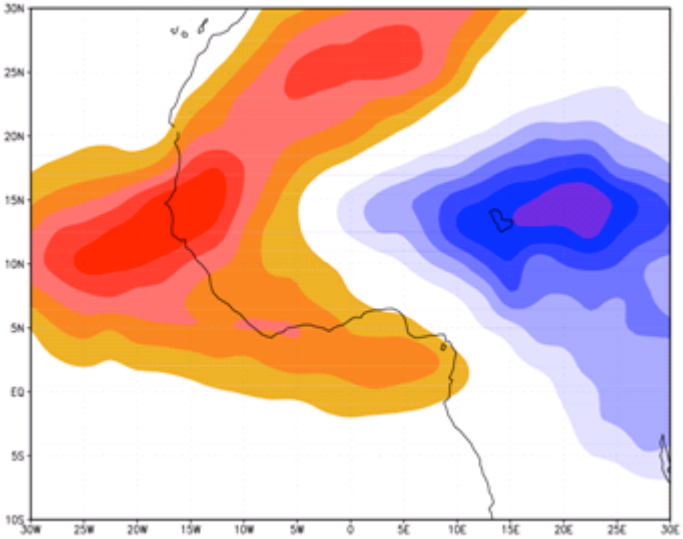


Guinean Mode

10-25-day : 10.2%, 8.8%, 5.6%

25-90-day : 20.4%

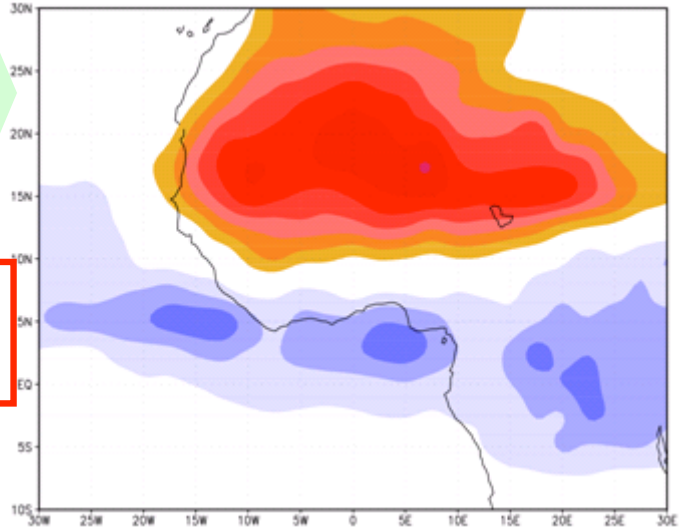
EOF2 / 7.96%



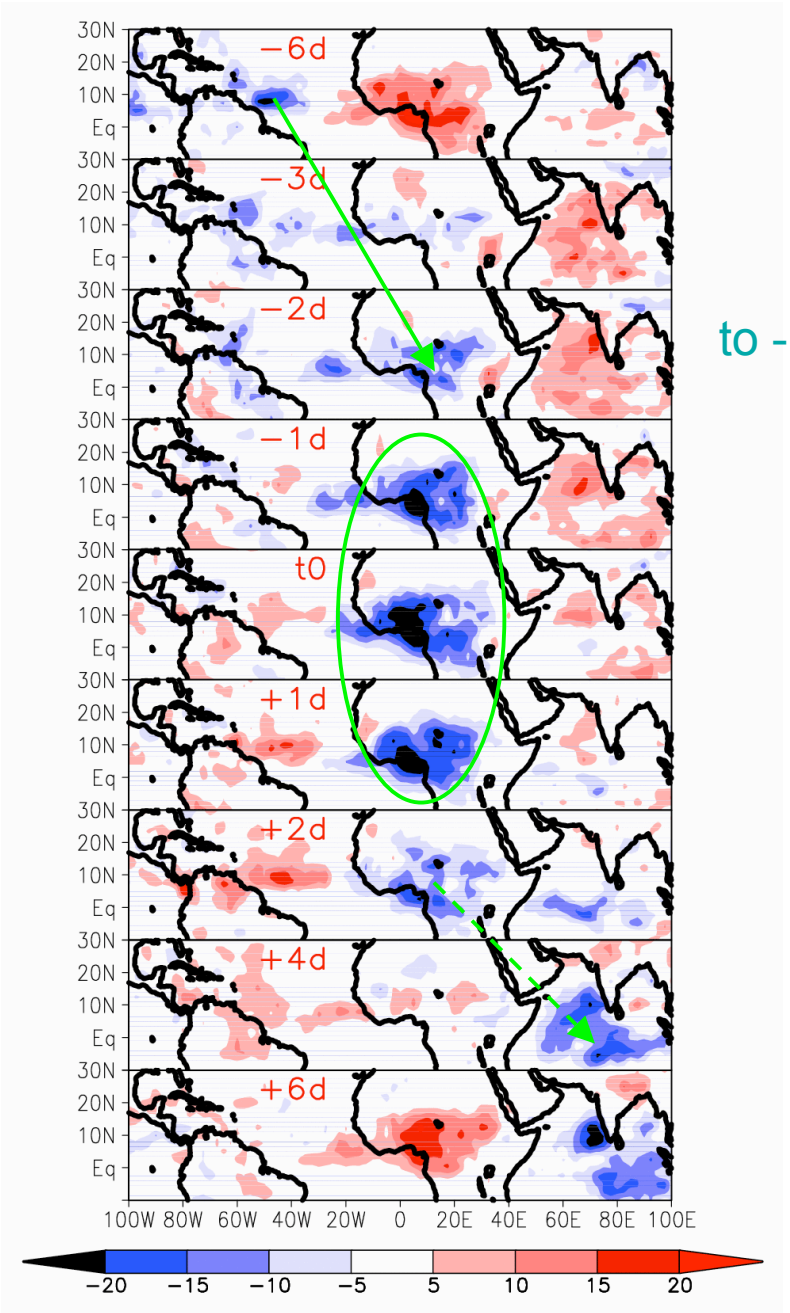
Spatio-temporal quadrature

Sahelian mode

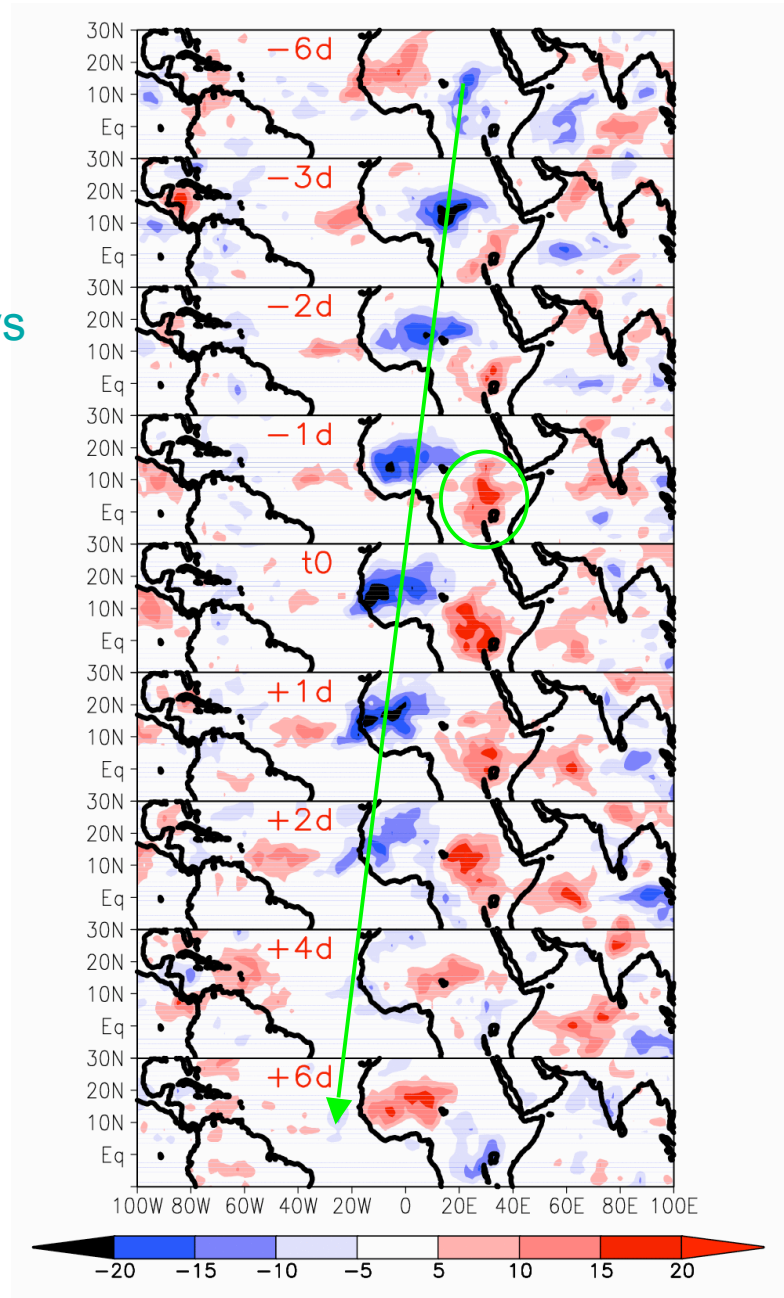
EOF3 / 6.12%



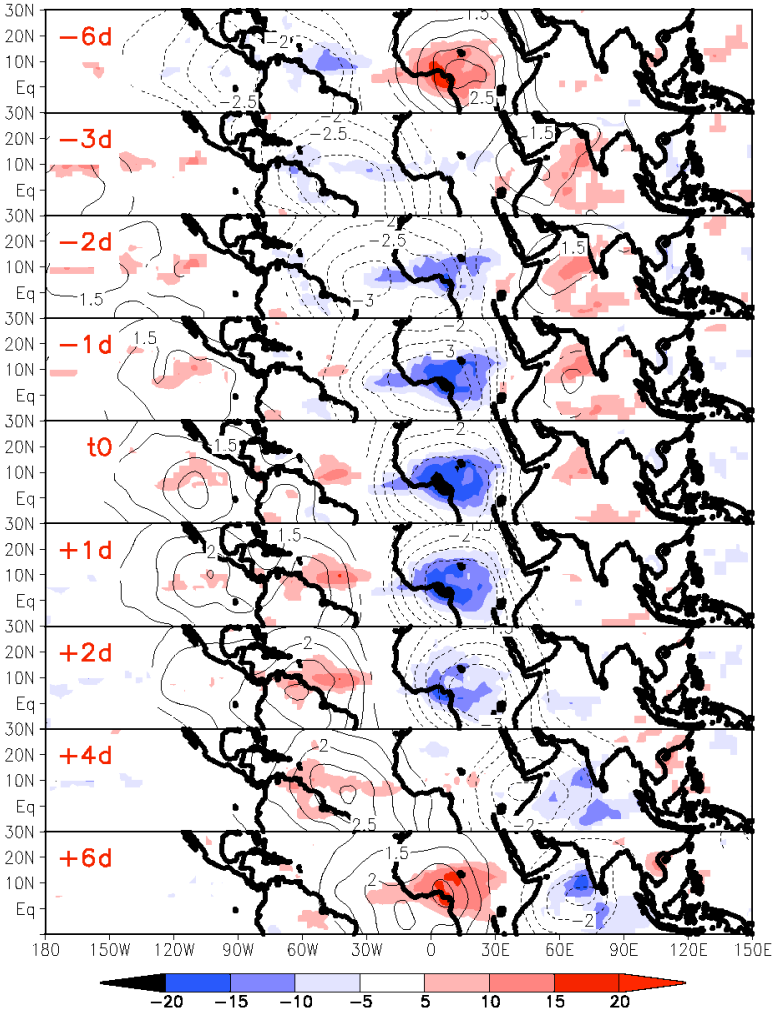
Guinean mode - **15-day scale** - Sahelian mode



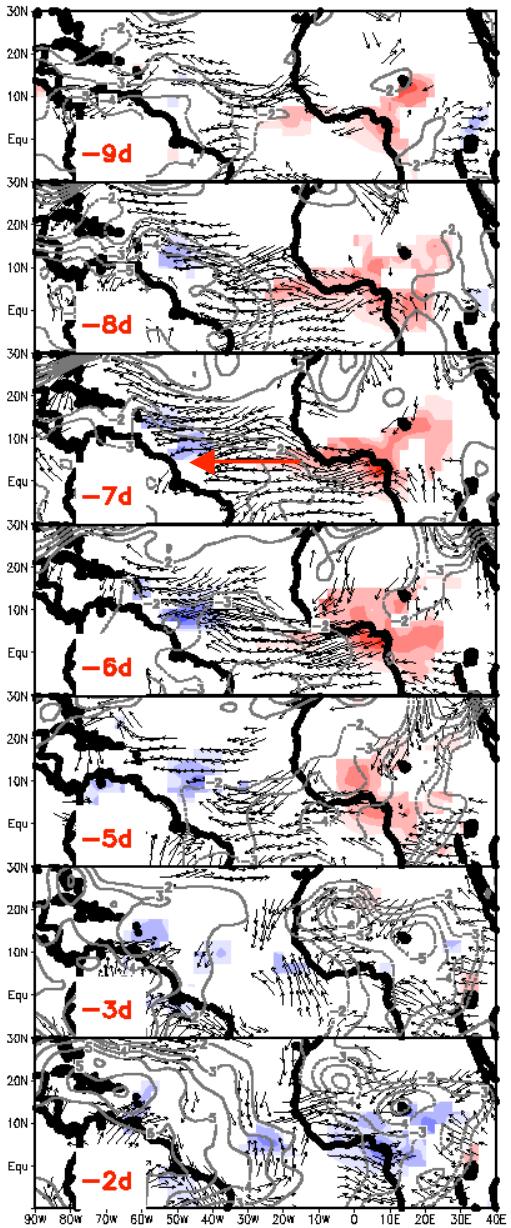
to - 6 days / + 6 days

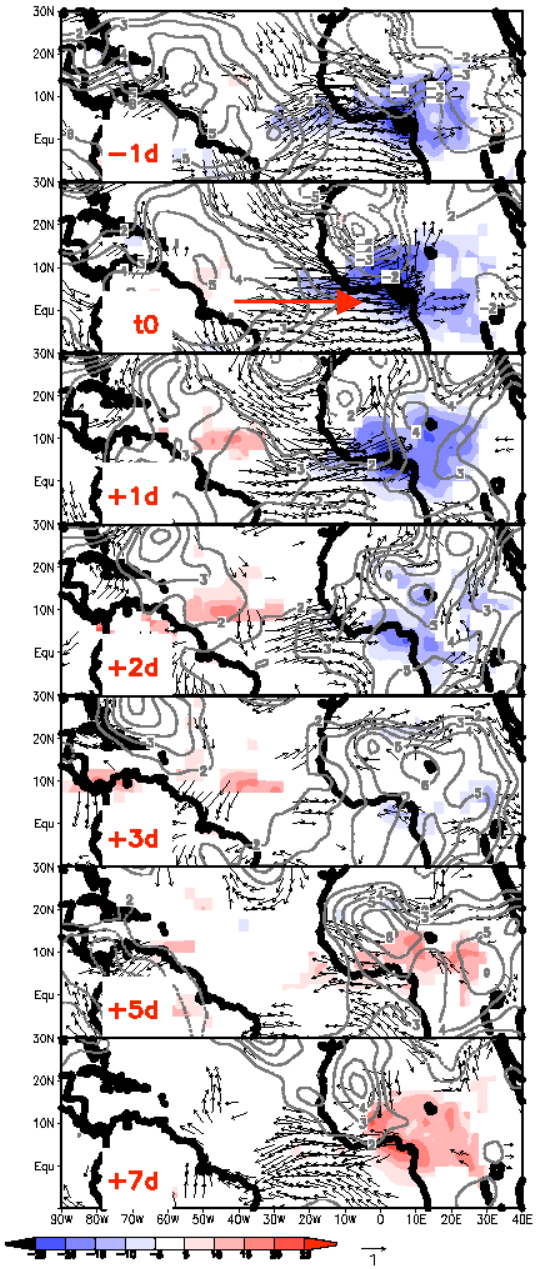


Guinean mode



OLR and 200hPa velocity potential

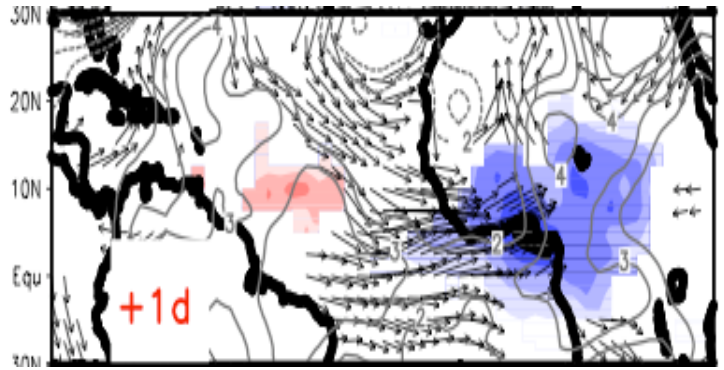




OLR and 925hPa wind and geopotential

Surface condition interaction hypothesis

Weakening of the Convection over Africa ---> less cloud coverage



- Increase of land surface temperature
- Increase in the surface pressure gradient land-ocean

- Rotation / strengthening of the monsoon winds towards Africa
- Increase of moisture advection toward the African ITCZ

- Increase of convection in the African ITCZ
- Decrease of convection in the Atlantic ITCZ

→ **Dipole structure**

Mechanism of interaction with the surface conditions

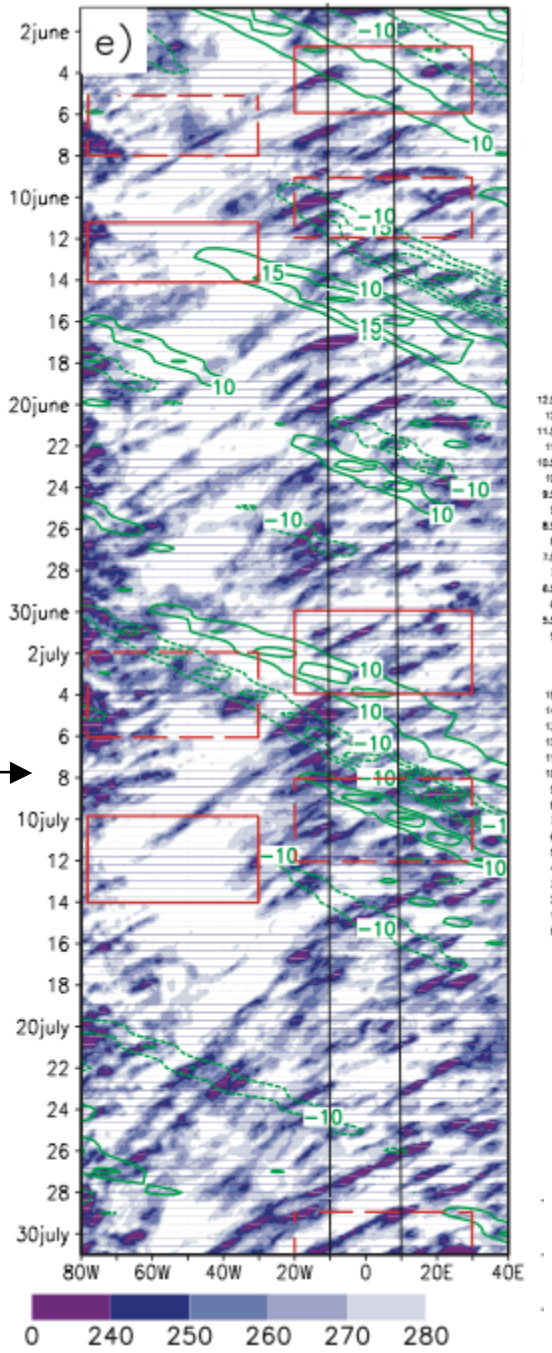
and

over a larger scale interaction with Kelvin waves ?

Blue: convective systems

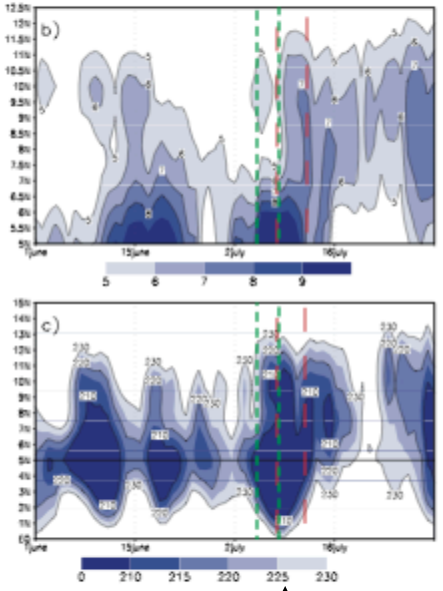
Green: Kelvin waves

Red rectangle: Guinean mode



Monsoon onset

1st June - 31st July 1984



5°N-12.5°N

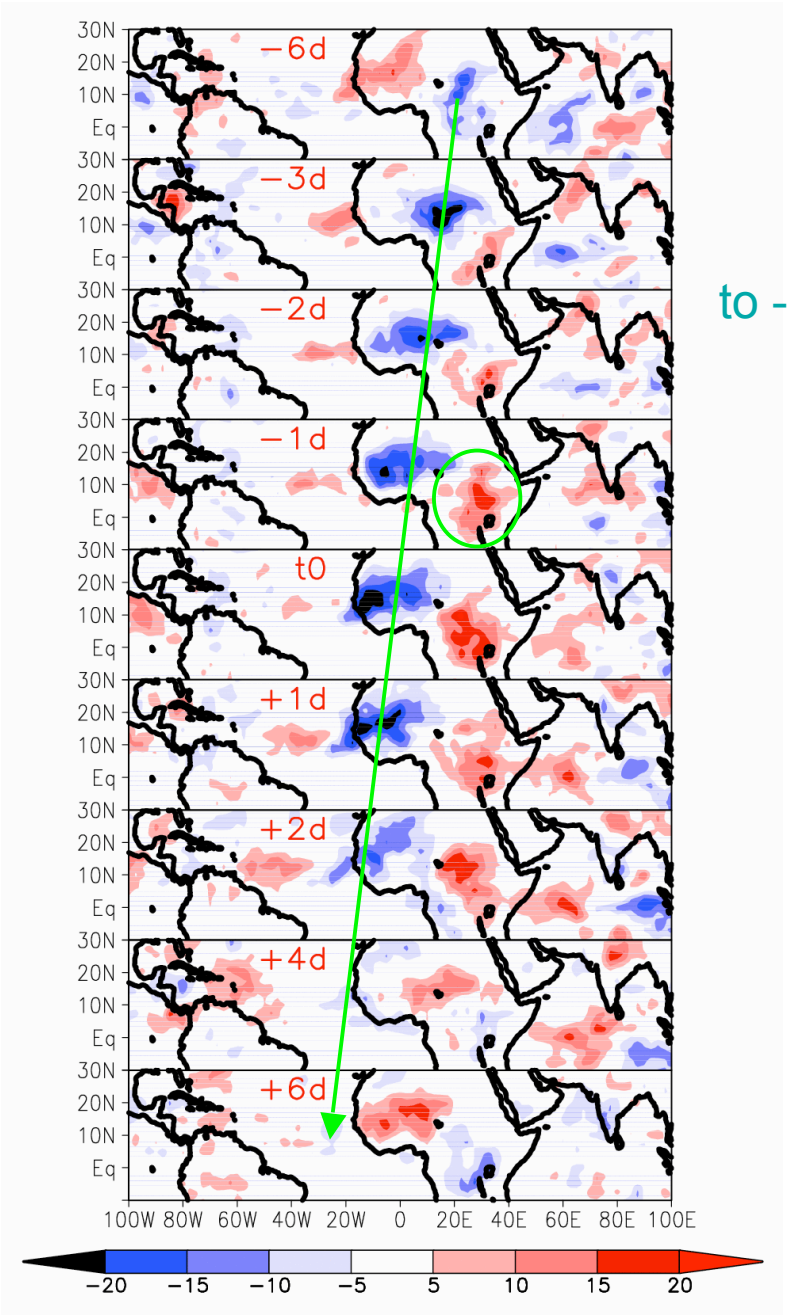
rainfall

0°N-15°N

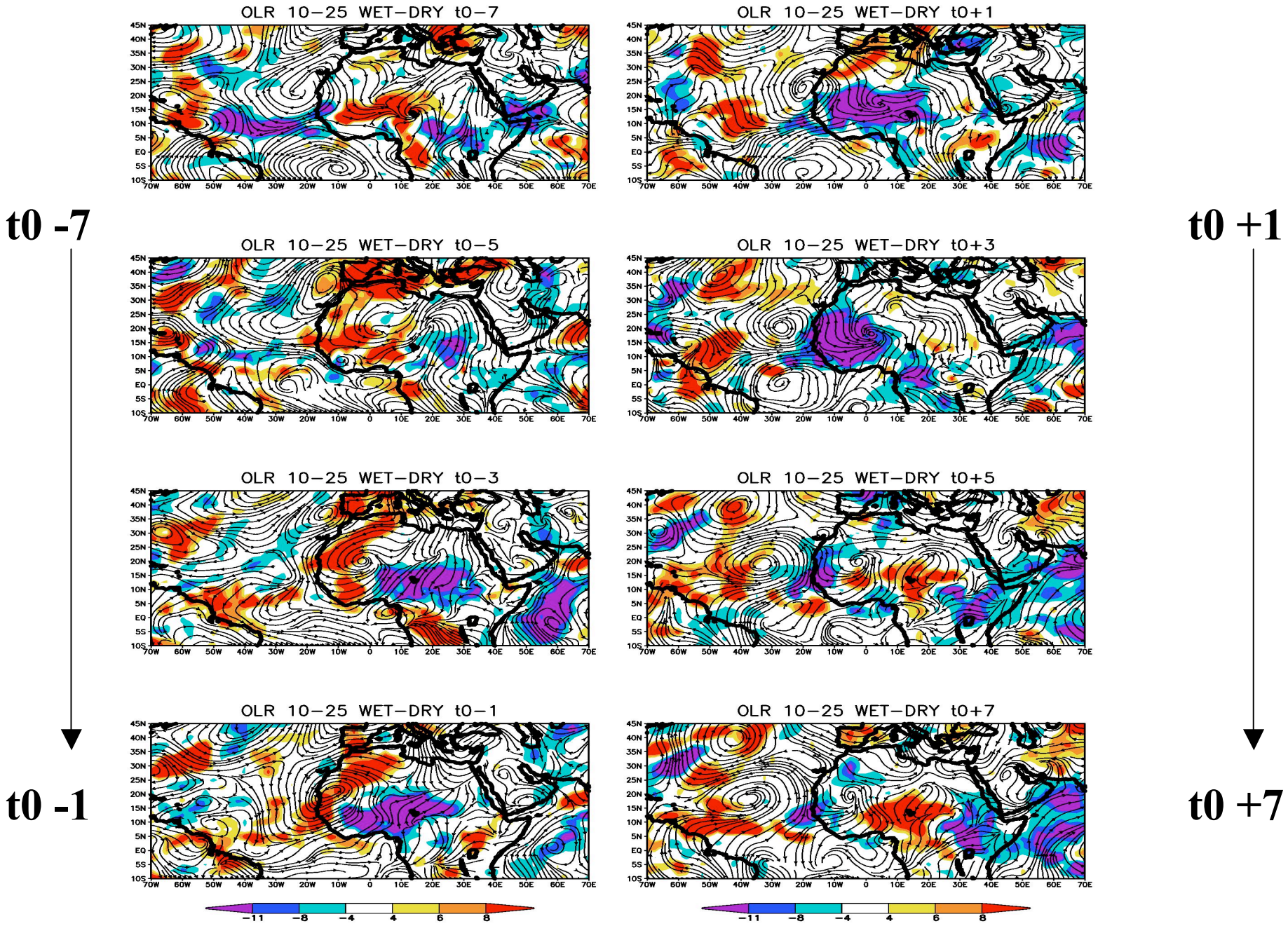
OLR

Monsoon onset

Sahelian mode - **15-day scale** -



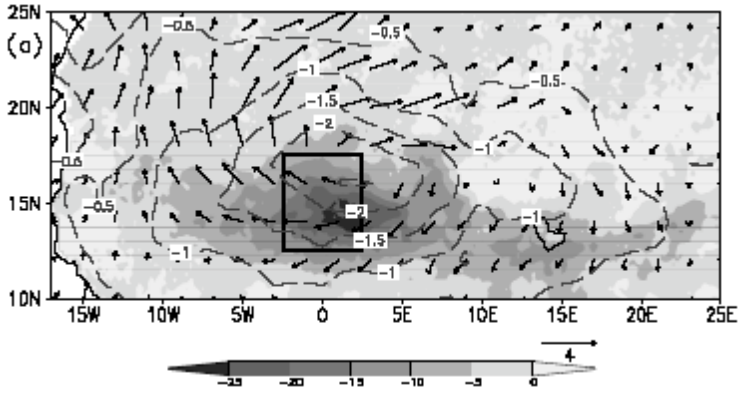
to - 6 days / + 6 days

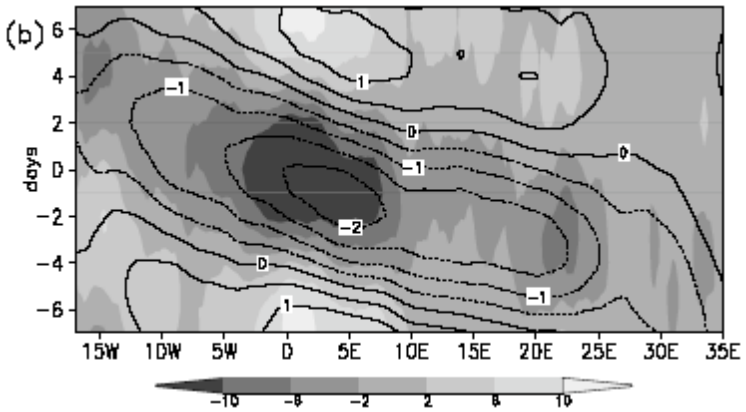


Sahel mode *OLR & wind at 925hPa*

C. Taylor's work 2007

Sensible heat flux (shaded),
T (contours) & V at 925hPa





Sensible heat flux, T at 925hPa

Convection ---> rainfall ---> high soil moisture

↓

Cooler PBL <--- Sensible heat fluxes decrease

↓

decreases relative vorticity ---> southerly flow to the west and northerly flow to the east

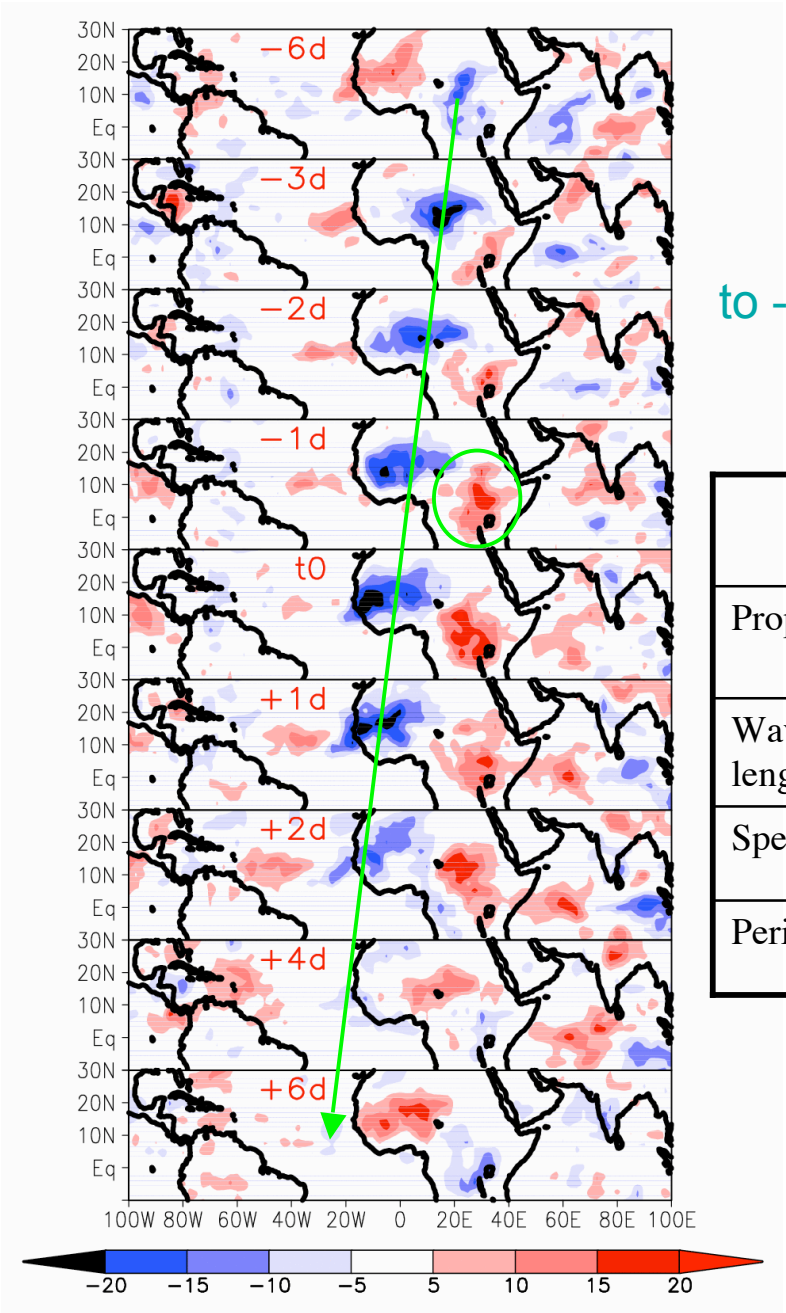
↓

Favors rainfall ahead ---> westward progression of the surface forcing

↓

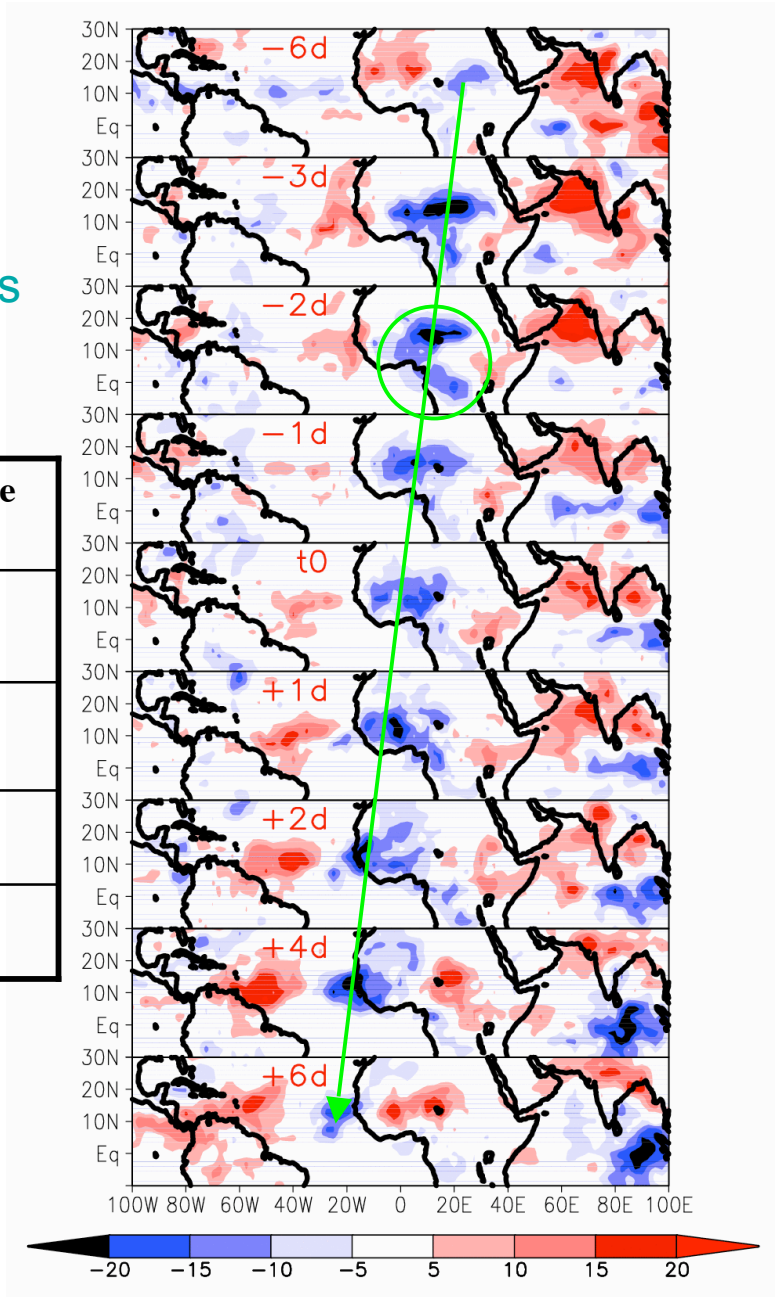
Convection development to the west

Sahelian mode - **15-day scale** - Eqt Rossby wave

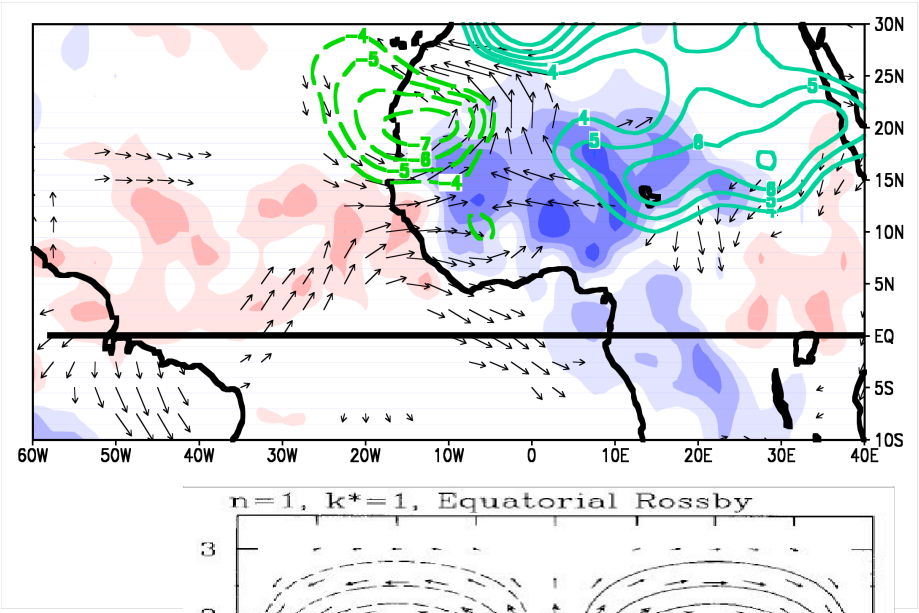


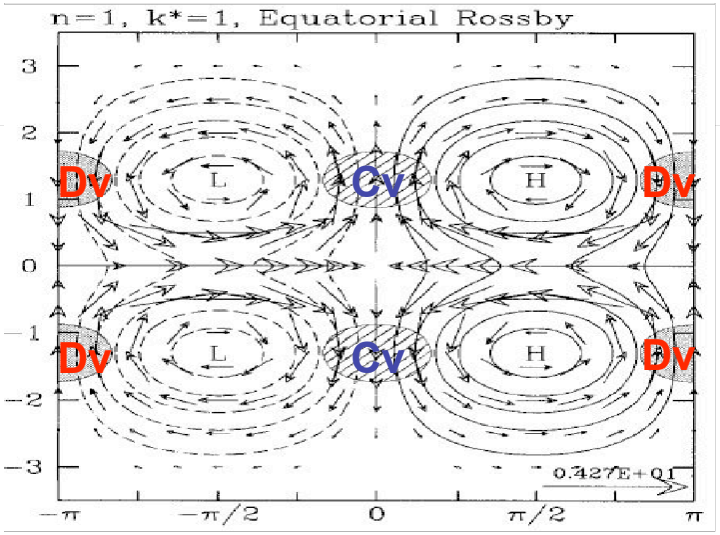
to - 6 days / + 6 days

	Rossby wave
Propagation	westward
Wave-length	7000 km
Speed	4.5 m/s
Period	18 days



Rossby waves over Africa



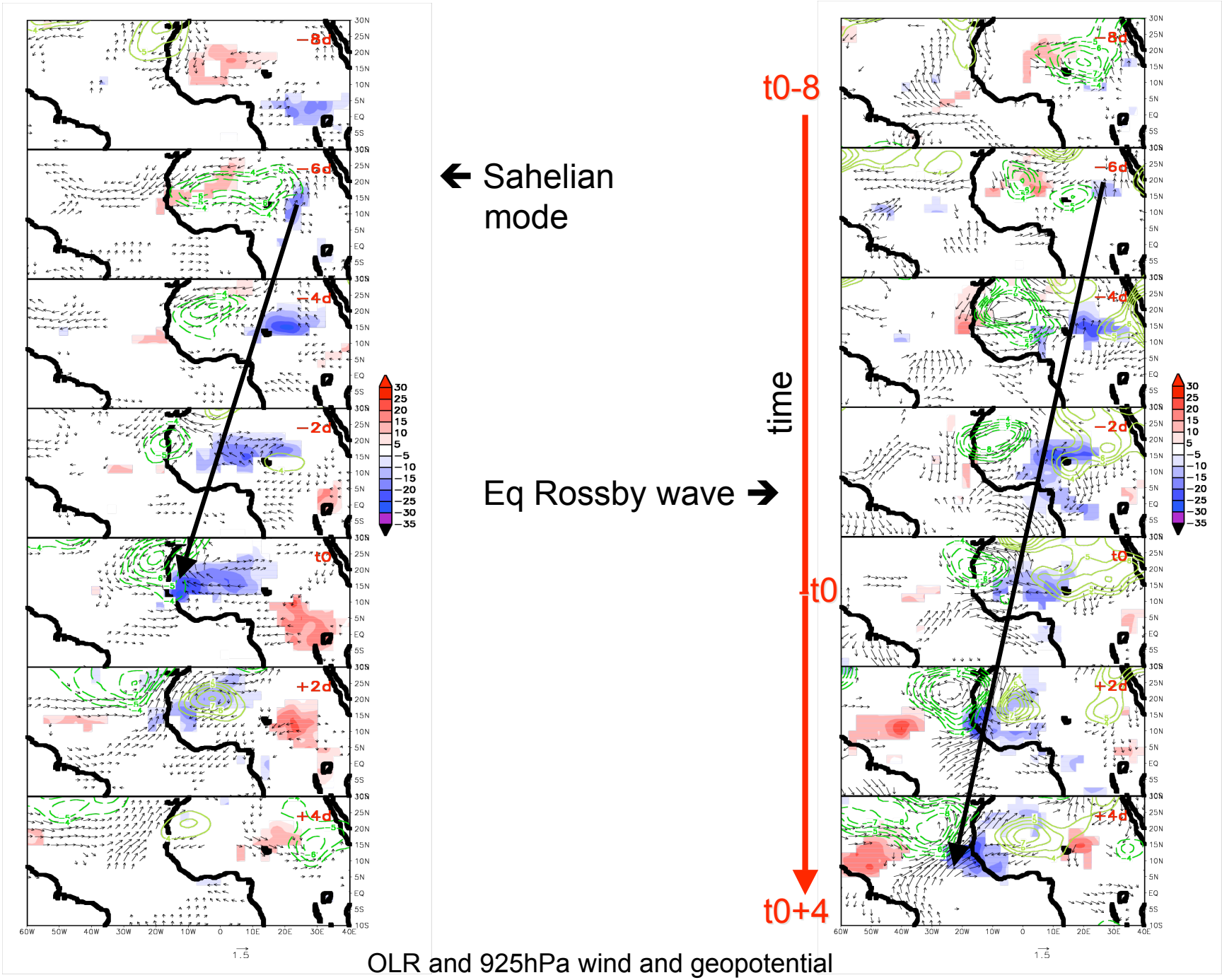


- Good coherence for convection and the associated circulation
- Symmetry apart of the ITCZ instead of the equator for all anomalies (not only convection)

Theoretical Rossby horizontal structure in a dry atmosphere

Matsuno 1966

OLR and 925hPa wind and geopotential



OLR and 925hPa wind and geopotential

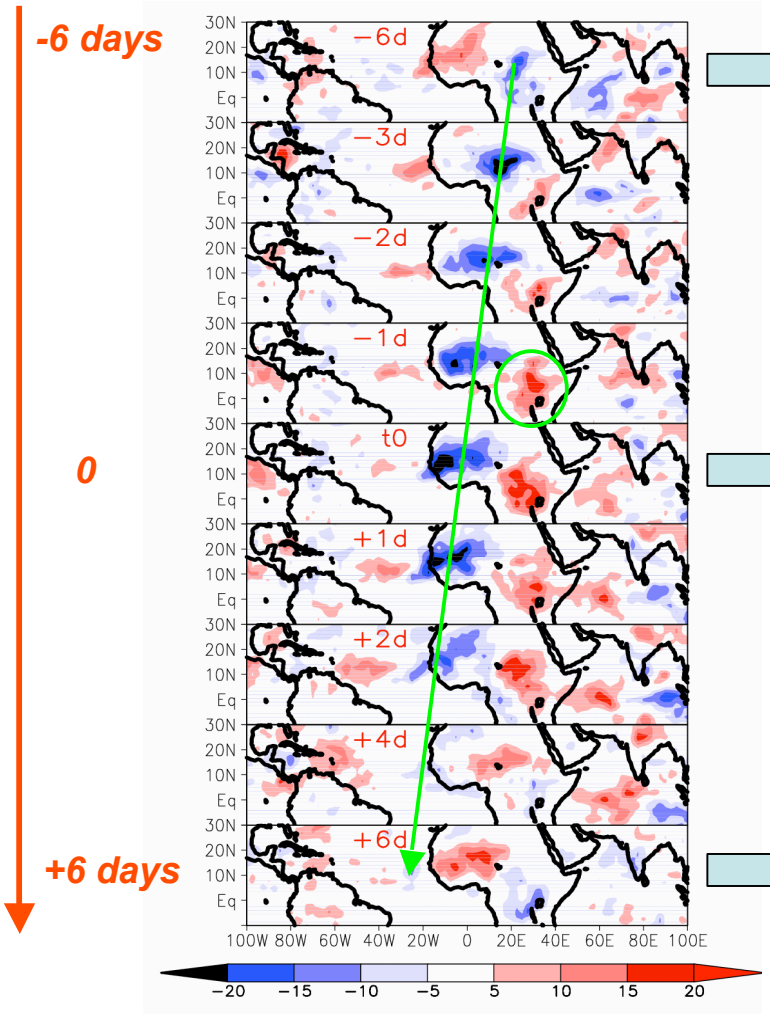
Links between Sahel mode and European weather types

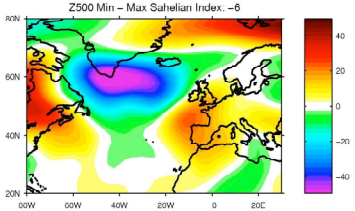
OLR

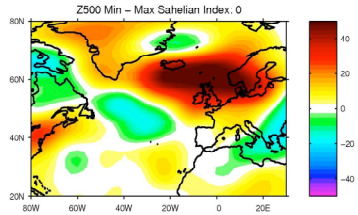
Geopotential at 500 hPa

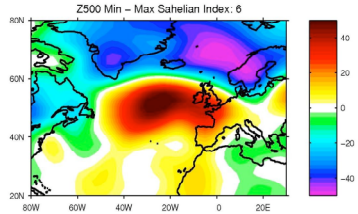
European weather type classification

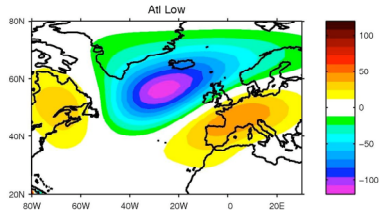
Cassou et al. 2005



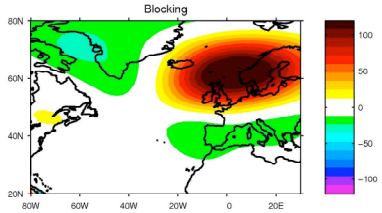




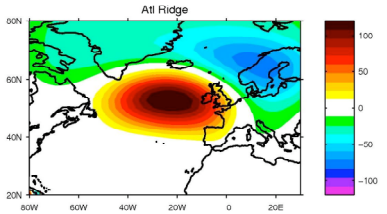




ATL Low



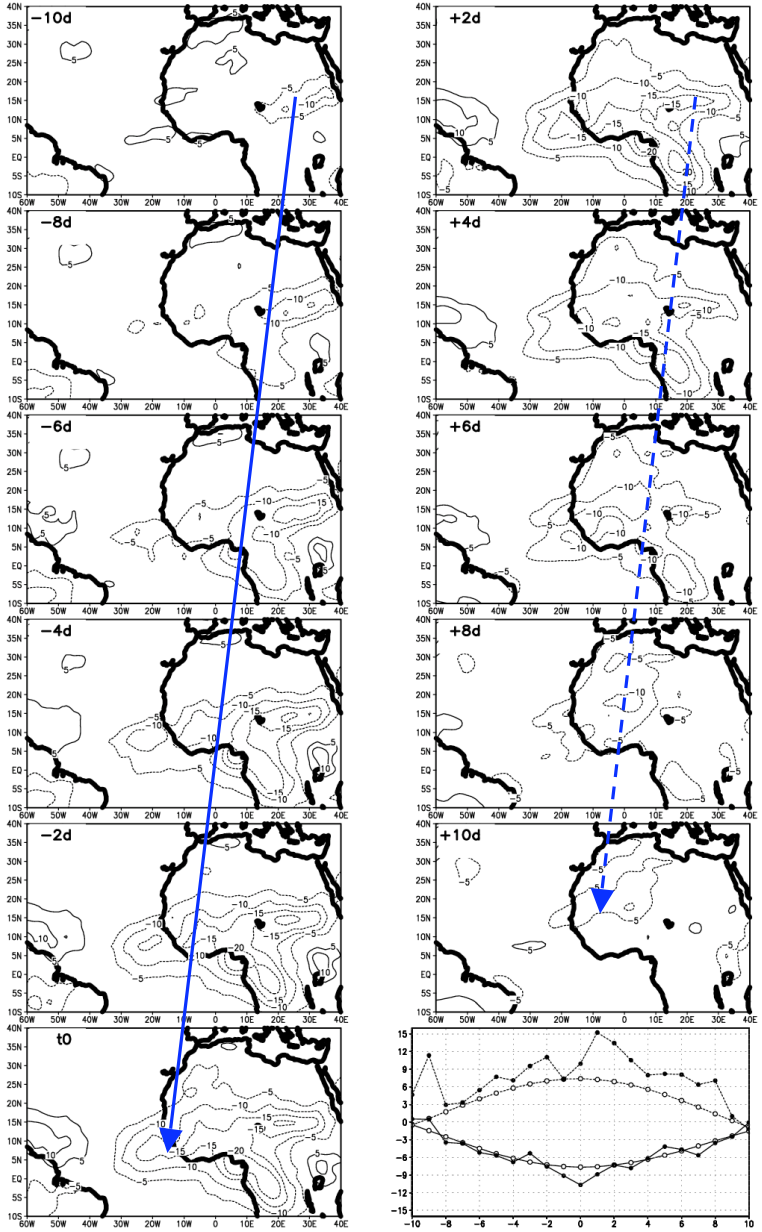
Blocking



Atl Ridge

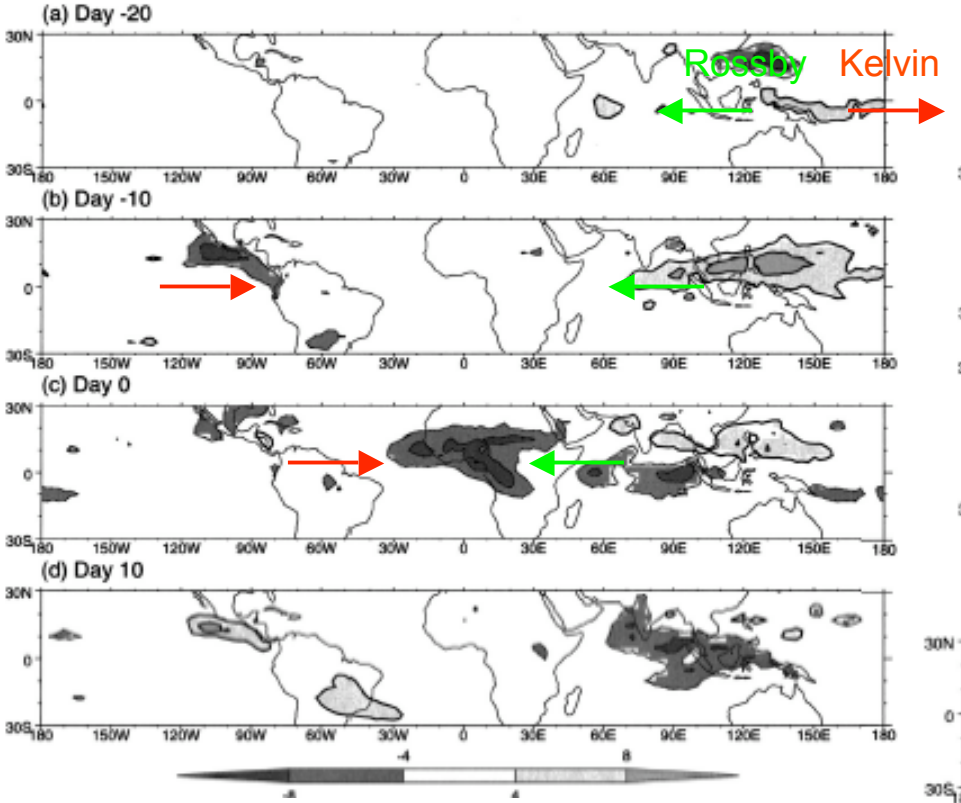
Composite of 25-90-day filtered OLR 1st EOF

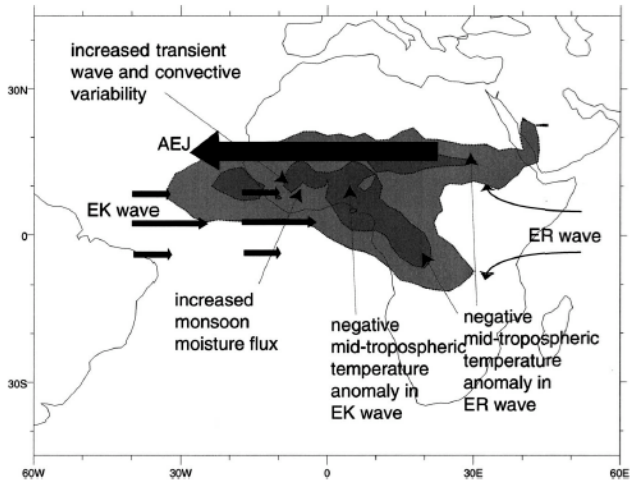
to - 10 days / + 10 days



Matthews' work 2004

OLR wet - dry event





mid-tropospheric temperature

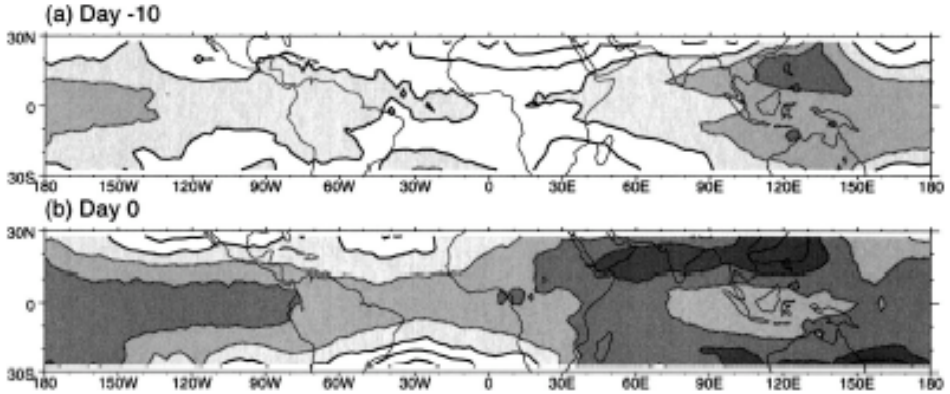
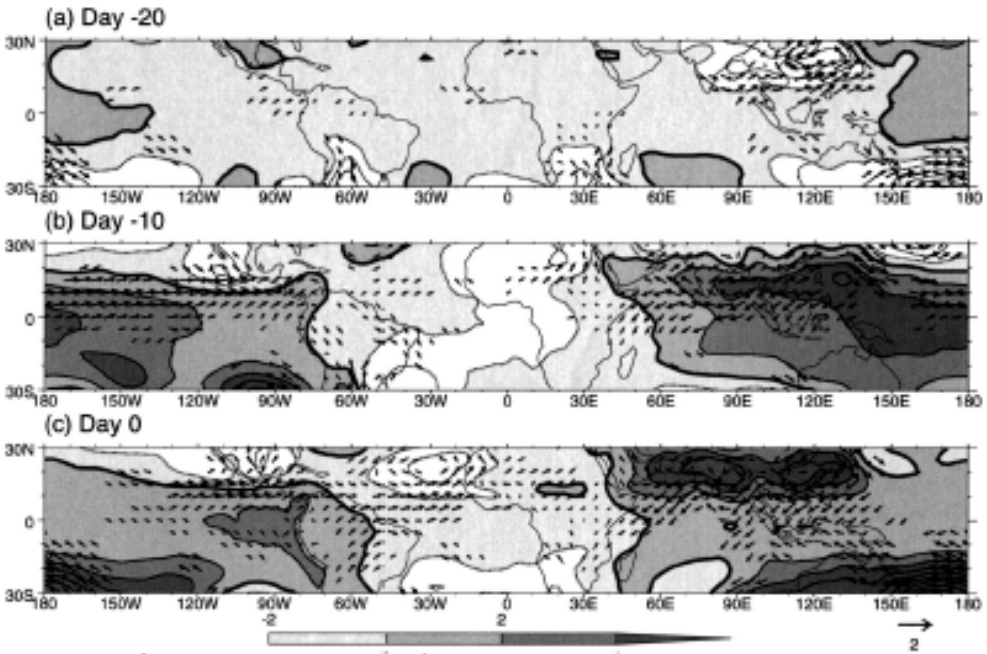
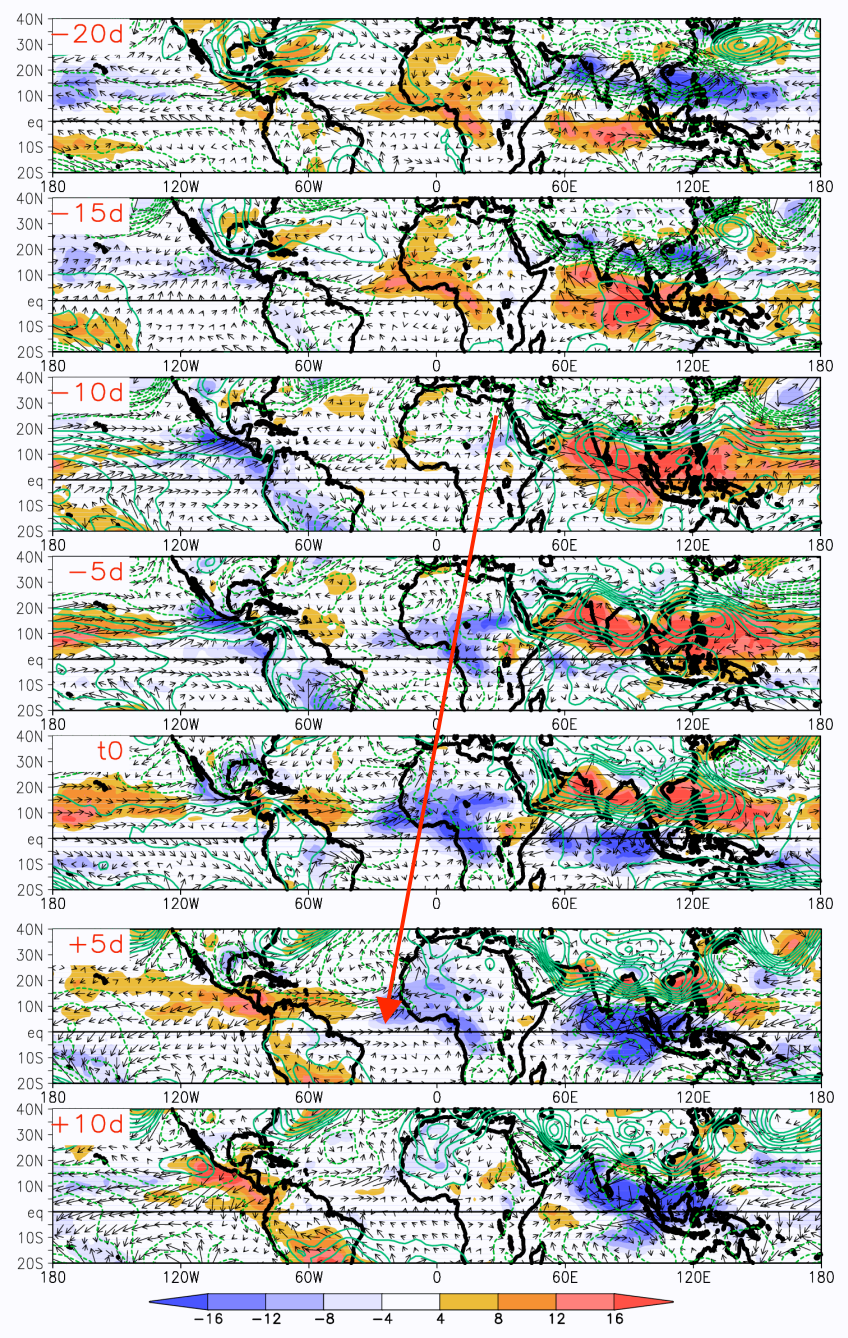


Fig. 6. Lagged regression maps of anomalous midtropospheric temperature MSU34 on (a) day −10 and (b) day 0. Contour interval is 0.08 K; negative values are shaded.



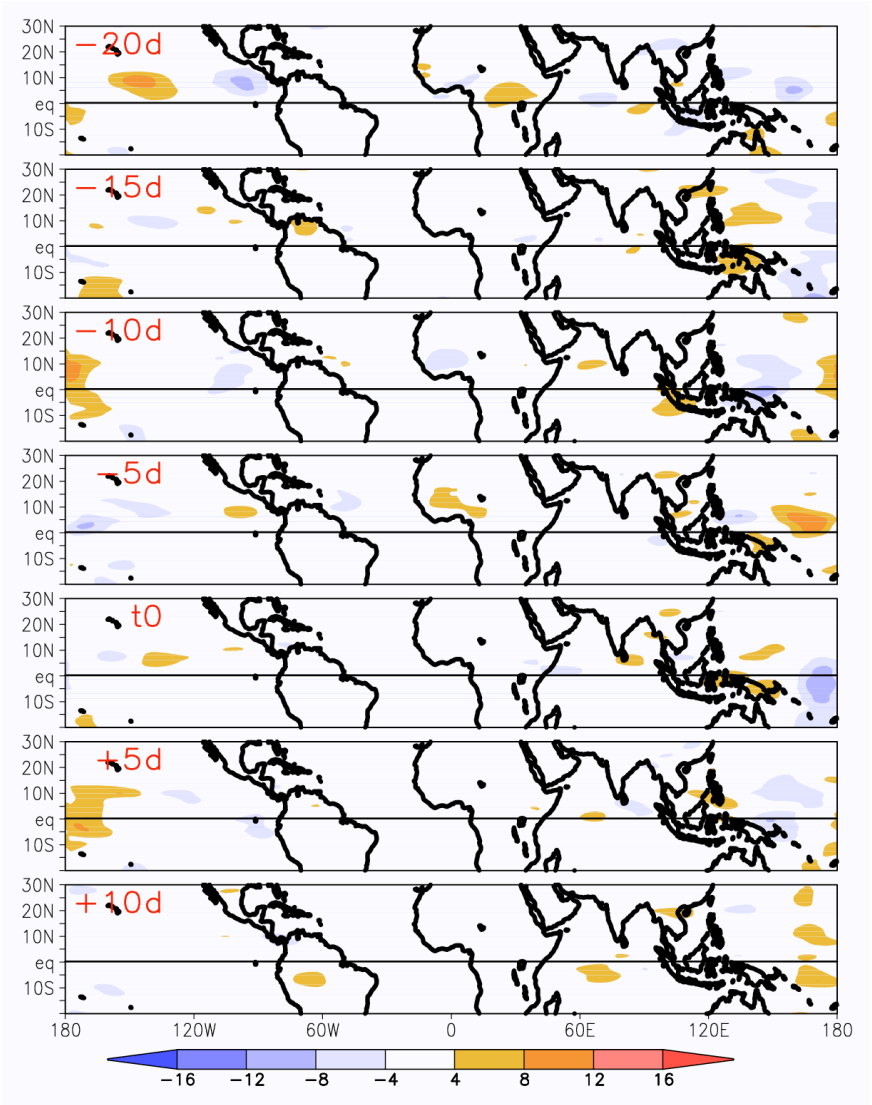
Geopotential & wind at 925hPa

OLR, V925hPa, Z925hPa

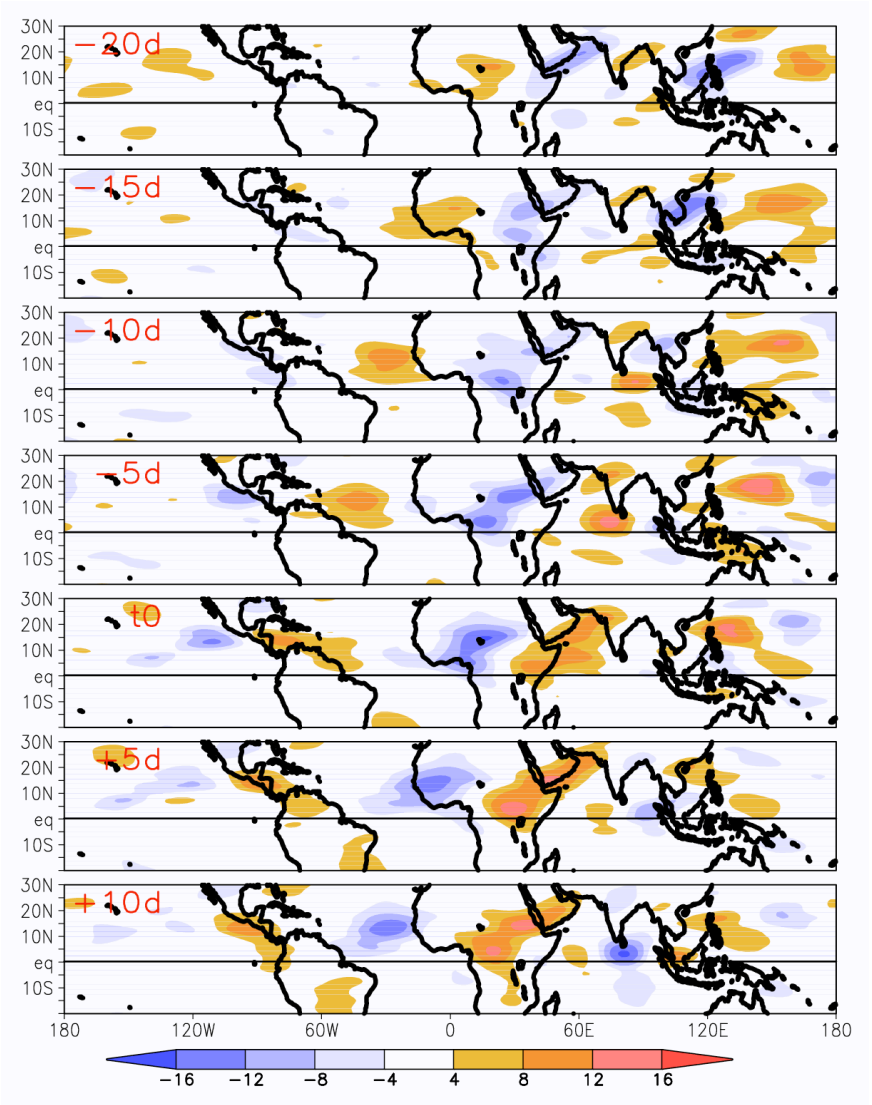


OLR and 925hPa wind and geopotential

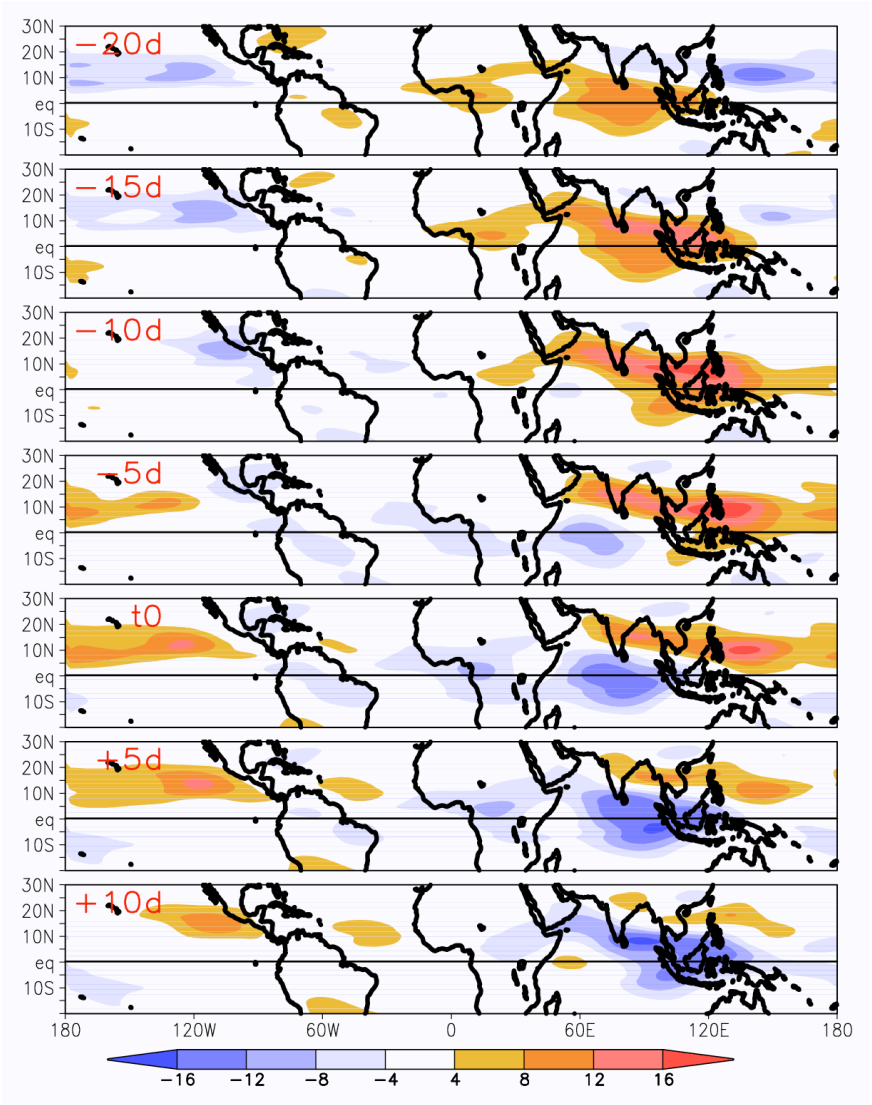
Kelvin filtered OLR



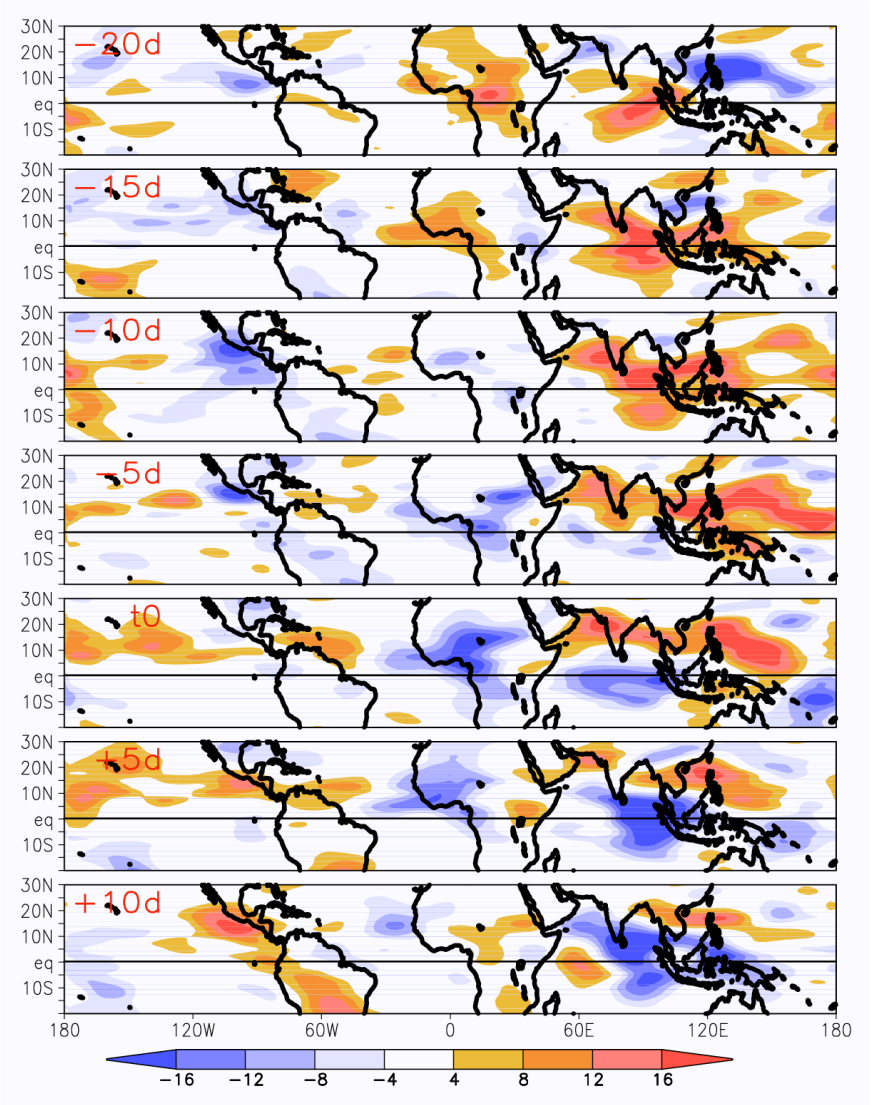
Eq Rossby filtered OLR



MJO filtered OLR

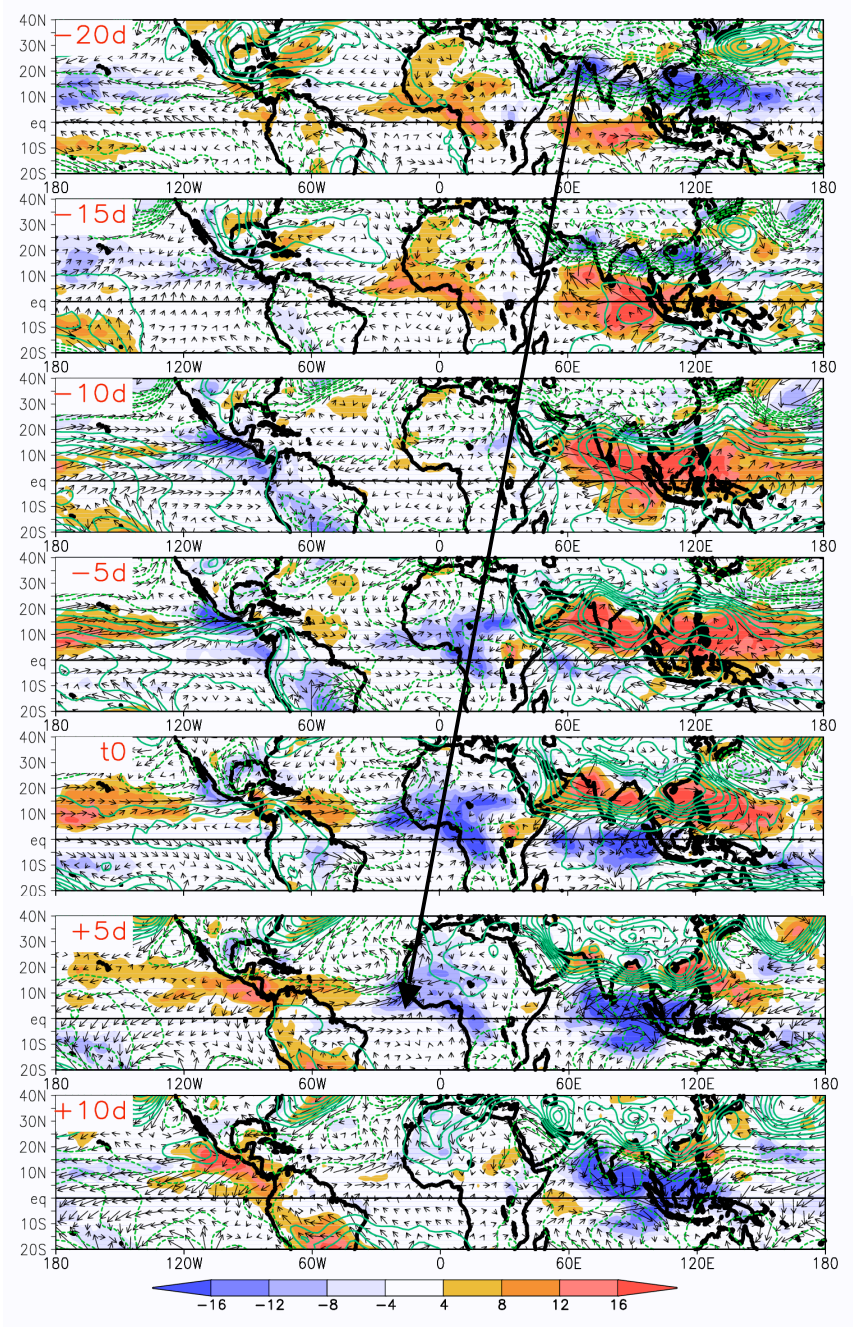


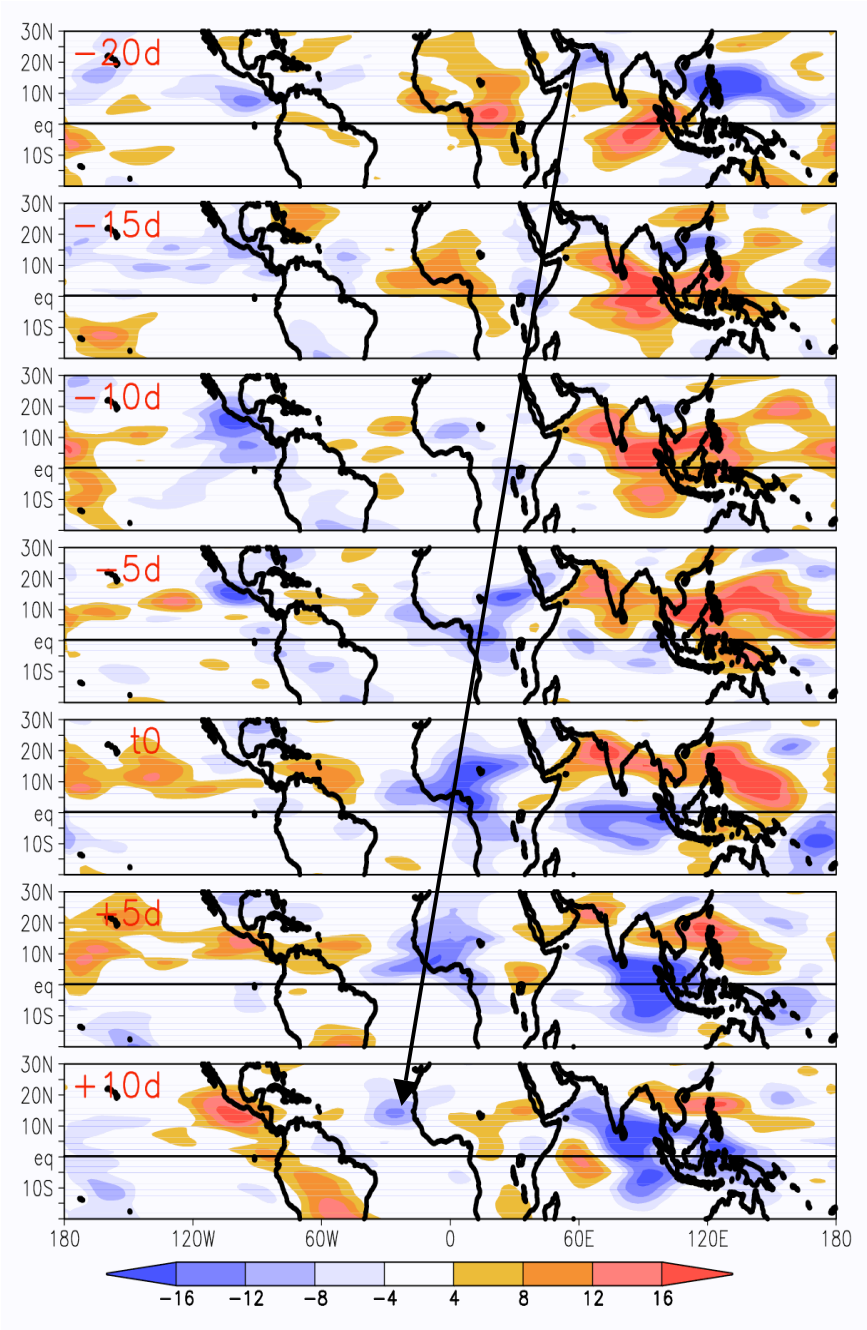
K+ER+MJO filtered OLR



25-90-day

K+ER+MJO





Conclusion

- Intra-seasonal variability modulates significantly convection in the African summer monsoon
- Three periodicity bands:
  - synoptic systems (African easterly waves and Kelvin waves)
  - ~ 15 days (2 main modes : West-Central Africa, Sahel)
  - ~ 40 days (the main mode on West-Central Africa)
- Connections with equatorial waves dynamics and MJO
- Possible impact on monsoon onset

- *More investigation on*
  - *connections between Indian and African monsoons*
  - *connections with European weather regimes*
  - *contribution to interannual variability*